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Rivers and Lakes Commission
—
REPORT
KASKASKIA RIVER VALLEY
—
Illinois-1910-1911

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GIFT OF
Illinois River
and Lakes Commission

REPORT AND PLANS

For Reclamation of Lands Subject to Overflow

IN THE

Kaskaskia River Valley, Illinois

Begun under the Direction of the

Internal Improvement Commission of Illinois

ISHAM RANDOLPH, T. K. CONDIT and
H. W. JOHNSON, Commissioners.

ROBERT ISHAM RANDOLPH, Secretary.

Completed and Published under the Direction of the

Rivers and Lakes Commission of Illinois

ROBERT R. McCORMICK, ISHAM RANDOLPH and
ARTHUR W. CHARLES, Commissioners.

ROBERT ISHAM RANDOLPH, Secretary.

BY

JACOB A. HARMAN, C. E.

1910-1911

Illinois, Dept. of Bureau and construction, Division of water

Bulletin no. 22

TO THE RIVERS AND LAKES COMMISSION
STATE OF ILLINOIS



SPRINGFIELD, ILL.
ILLINOIS STATE JOURNAL CO., STATE PRINTERS
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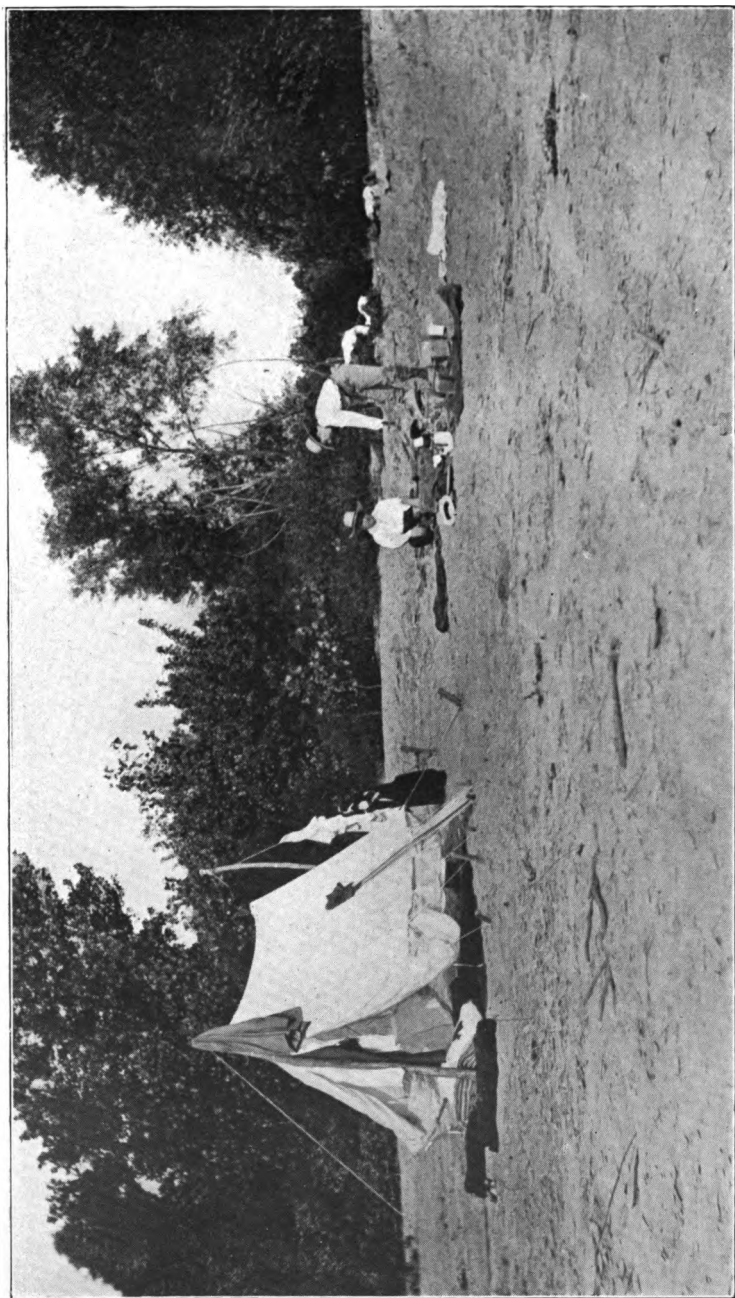
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- Figure No. 1.....Rain-fall Diagram, 1901-1910 by Months.
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Figure No. 3.....Outline Profile of Kaskaskia River.



Reconnaissance camp. Hon. E. J. Smejkal (Chairman, Committee on Canal, River Improvements and Commerce, Forty-seventh General Assembly) seated; F. W. DeWolf, Director State Geological Survey, standing.

PREFACE.

In the report with plans for the reclamation of lands subject to overflow in the Kaskaskia river valley, by Jacob A. Harman, C. E., the Rivers and Lakes Commission presents the results of work and study extending over about five years, and desires to make acknowledgement to the United States Geological Survey, to the Geological Survey Commission of the State of Illinois, to the Internal Improvement Commission of Illinois, and to the officers and employes of the several commissions concerned in the preparation of the material upon which this report and plan is based.

The plan set forth in this report is an ideal one and is, to our minds, a model engineering study for the comprehensive reclamation of all of the lands subject to overflow in the Kaskaskia river bottoms. It is not intended to imply that under this plan the immediate reclamation of every part of the Kaskaskia river valley is to be provided for, but we believe that no drainage scheme for the reclamation of any portion of the Kaskaskia river valley should be carried forward without a consideration of the plan outlined in this report, and that no works, levees, ditches or pumping plants should be constructed in this valley without conforming to the essential requirements laid down in this plan.

In this connection a word or two on the physical features of drainage work that must be considered in the successful reclamation of any large area within a drainage basin is pertinent.

In a well drained river basin the main stream and its tributaries are properly adjusted to each other with respect to width, depth and slope. The head waters as they flow down the valley from the network of upland streams are properly accommodated at junction points by channels adequate to carry their combined volumes. Each succeeding increment of flow is accommodated by a corresponding increase of stream cross-section. The volume of the main stream is the combined volume of all its laterals. If this were not so, if the upland were well drained and the main channel not of sufficient section or slope to properly discharge this drainage, the result would be overflowed bottom lands—swamps. This is the condition we are attempting to correct by drainage; yet in many instances this is the very condition that is being produced. In many places drainage works have been projected without providing suitable outlets for water in the lower portions, making the drainage work less effectual than it would otherwise be and aggravating swamp conditions in the lands below. It is not sufficient to dig ditches through a large area and discharge the water into streams that are not adapted

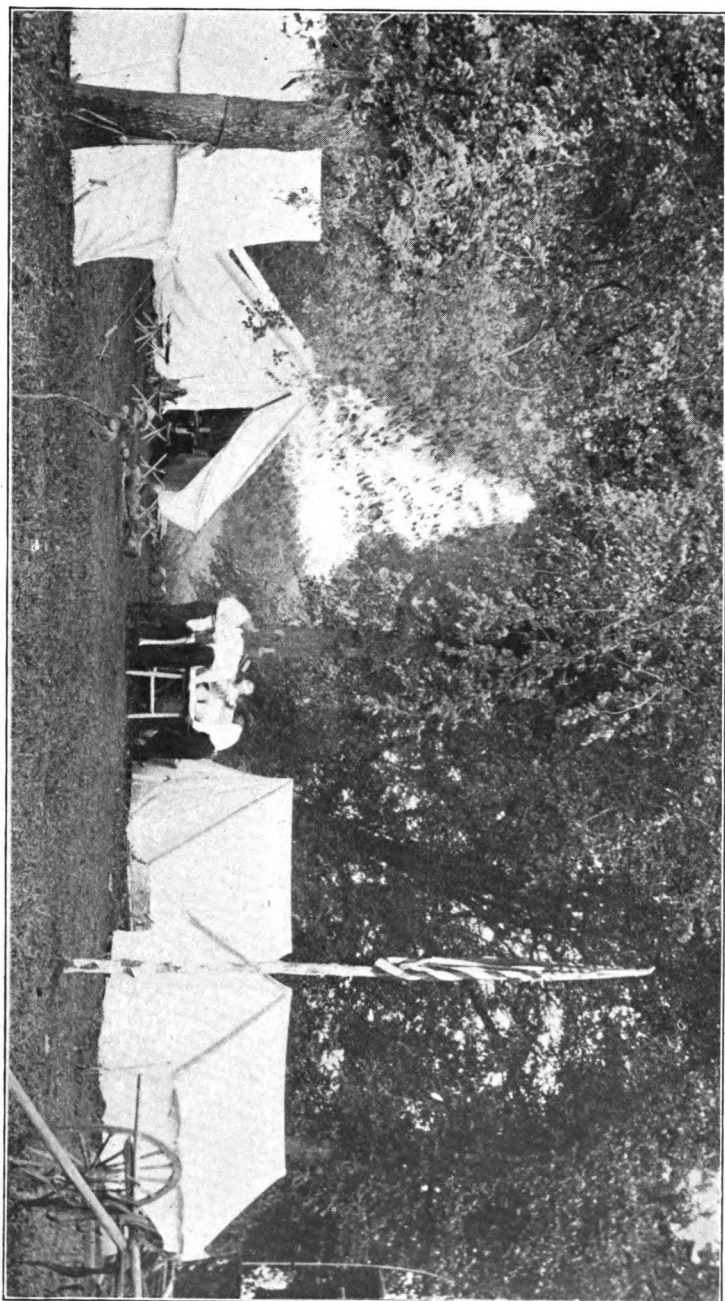
to the increased rate of flow. This results in flooding lands not previously subject to overflow and amounts to a mere exchange of land values in which there is neither right nor equity. So we say that a swamp, if included within a single river system, must eventually be reclaimed as a unit and this applies to by far the greater area of our Illinois swamps where the reclamation must be accomplished by pumping or gravity drainage into natural streams already established. In such cases those natural streams must be enlarged and adjusted as far down their courses as necessary. That is the way nature drains; that is the way we must do it. If a drainage district, for example, must provide a suitable outlet for the surplus water that it discharges from the district and enlarges the natural channel or digs a new one beyond the district boundaries far down to a remote point at which a suitable outlet is provided, that channel will benefit by drainage all the country that it passes through, whether the drainage authorities like the result or not. Such a benefit to the lower region must be paid for by the people of the district. In other words they must be assessed for benefits to lands in which they have no immediate interest. We might illustrate a score or more of conditions of similar purport, all of which prove substantially that logically, ethically and financially the drainage of a swamp should comprise all the lands in a particular basin. There should be participation in the expense by every land owner. or there will be an inequitable distribution of expense.

The force of these physical laws is apparant, but everyone who has had to do with drainage developments in Illinois has encountered the difficulties produced by the divided jurisdictions of disconnected, often antagonistic, drainage districts in the same watershed. These have been developed without any regard for the drainage problem of the watershed in its entirety, and often without just regard for the rights of other districts in the same watershed. The physical laws have been defined and they are absolute. The present difficulty seems to lie in the artificial laws. They have apparently developed in the same disorderly progress as the drainage developments. They have been amended and added to from time to time to meet new phases and conditions of the drainage development until they have become so voluminous that it is inconvenient and even difficult for engineers and commissioners to follow them without making mistakes. Not only this, but they are inadequate to meet the conditions imposed by the broader and more comprehensive scale of development herewith proposed.

The most that can be said for the present drainage laws of Illinois is that they work fairly satisfactorily for areas up to a few thousand acres; but are unwieldy and practically useless for the organization of a machinery for the carrying out of such a plan as is here presented.

The reclamation of the overflowed lands of many of the smaller rivers of the State, of which the Kaskaskia is characteristic and one of the larger, presents a problem which may be considered two-fold.

First—The correction and maintenance of the channel of the main stream and its tributaries within the overflowed areas, which will tend to reduce the maximum flood stage and materially reduce the duration of floods.



Survey camp near Vandalla.



Survey launch above Vandalla.

Second—The grouping of the overflowed lands into suitable drainage units which shall each be protected from overflow by levees and drained by an adequate system of interior ditches with a sufficient outlet into the main stream either by gravity diversion channel or by the construction of a pumping plant.

It is a well established policy in this State that all improvements of a local nature should be made by a tax or assessment based upon the benefits. To carry out a proper design for the reclamation of such areas as we are considering, it is necessary that the river correction and maintenance as above described, be considered as a whole and under the management of some one authority with adequate power to carry on the work in a proper manner. The benefits from such portion of the work would extend to all of the overflowed lands and, therefore, may be considered general, and while the taxes for such improvement should be limited to the lands that are benefited, they nevertheless might equitably be made either by direct assessment upon the valuations or by a classification for benefits. The benefits to the individual drainage units resulting from the construction of levees, ditches and an outlet for the ditches would be limited to the area thus directly benefited and the funds for this portion of the work should properly be provided by a special assessment of such lands based upon the benefits.

As an outline for a method of establishing a drainage district to include all of the lands to be benefited by such an improvement and for providing for the proper organization and management of the same, we make the following suggestions:

First—That whenever a petition of 20 per cent of the adult owners of any contiguous tract of land in need of drainage in any county is filed with the judge of the county court of such county, an election shall be called to vote upon the question "Shall the territory as described in the petition be organized into a drainage and levee district for agricultural and sanitary purposes?"

Whenever such petition recites that the overflowed lands in an adjacent county or counties would be benefited by a continuation of such drainage district, and whenever similar petitions are filed with the judges of the county courts of such adjacent counties, then such judges shall be *ex officio* a board of election commissioners and shall call a joint election and submit the question as above for the organization of a drainage district including all of the lands as set forth in the petitions to the judges of the various counties. If the majority of the adult owners of the land in said proposed district vote in favor of the organization of the same, said judges acting as election commissioners shall declare such territory organized to be a drainage district.

Second—There shall be three drainage commissioners elected by the adult owners of land in each county in which a portion of said drainage district may lie, and each of said commissioners shall be an owner of land in said district. The judge of the county court of each county shall call an election for the purpose of electing such commissioners. In providing for the election of these commissioners cumulative voting should not be permitted.

Third—The judges of the county courts acting jointly should declare the election of the commissioners and notify the commissioners elected to meet at a certain time and place for the organization of the board of commissioners, which shall consist of all of the drainage commissioners elected from the several counties. Said board of commissioners when so elected shall be vested with full authority over the drainage district, which shall be organized as a municipal corporation with power to elect or appoint all necessary officers and employes, including engineers and attorneys; to levy taxes, borrow money and to construct and maintain all necessary improvements, including straightening of streams, levying, ditching, pumping plants and other works.

Fourth—The funds might be raised as follows:

1. For the maintenance of the organization by direct tax upon assessed values of lands.

2. For the straightening of the main stream and tributaries and the maintenance of the same, either by direct tax based upon assessed valuation or by special assessment upon the lands which are to be classified according to benefits.

3. For the construction of levees, ditches, diversion channel or pumping plants for the unit areas of drainage by special assessment upon the lands benefited.

Fifth—The improvement of any unit area of drainage may be undertaken upon the initiative of the board of commissioners, or upon a petition of the adult owners of land within such unit area.

Sixth—The commissioners shall have power and authority to annex to the said drainage district any lands that may be benefited by the work of said proposed drainage district, and to accomplish such annexation said commissioners may file a petition with the county court of the county in which said lands to be annexed are located, and upon a hearing the judge of such county court shall determine whether such lands are benefited, and if so they shall be annexed to said district and become a part thereof the same as if a part of the district as originally organized.

Seventh—The commissioners shall appoint three disinterested appraisers to classify the lands for benefits and such classification when made, should be filed with the county court of the county in which said lands are located, and any owner of land should have the right to object to his assessment before the county court and the right to a jury trial upon the benefits to his land if demanded.

Eighth—The drainage commission should be vested with power of eminent domain for acquiring right-of-way for all straightening of streams, levees, ditches and other works.

The foregoing is a brief outline of what we consider some of the essential points for the draft of a bill for a drainage law which would be acceptable to the owners of such lands and would not be unnecessarily cumbersome. The principal objection to the organization of drainage districts of large areas under the present law consists in the fact that there is a large expense in the matter of preparation of petitions, the procuring of signatures of a majority of the owners of lands and a

hearing before the county court in case of a contest. All of this expense and labor must be furnished by the petitioners at their own risk and if, for any reason, the district should fail to be organized, this expense would be an entire loss to the petitioners. It would require the expenditure of many thousands of dollars to prepare the necessary petitions and procure the necessary signatures for the organization of such an area as the Kaskaskia river valley into a drainage district under the present laws, and after it was organized the powers of the commissioners would be so limited that they would not be able to make progress, owing to the possibilities of delay and interference by objectors.

The Rivers and Lakes Commission recommends, therefore, that the General Assembly of the State carefully consider the ideal engineering plan herewith presented for the reclamation of the lands subject to overflow in the Kaskaskia river valley, and devise some modification of the present drainage laws, or some new enactment, that will make the realization of this project legally practicable.

To the Honorable Rivers and Lakes Commission of Illinois:

GENTLEMEN—Herewith are submitted preliminary plans and estimates of cost for the reclamation of the lands subject to overflow in the Kaskaskia river valley from the Shelby-Fayette county line to the mouth of the Kaskaskia, in Randolph county. This report was nearly completed under the direction of the Internal Improvement Commission of Illinois, active work on the study of the problem having been begun in April, 1910.

In addition to the plans and estimates for the reclamation of the lands in the Kaskaskia valley, plans and profiles for the improvement of the channel of Shoal creek (one of the principal tributaries of the Kaskaskia) are included from a point about 3 miles north of the Vandalia Railroad bridge, near Greenville, in Bond county, Illinois, to its confluence with the Kaskaskia river.

The subject matter of this report will be treated in the following order:

1. Data, Maps, Plans and Profiles.
2. General Description.
3. Bridges.
4. Districts now organized.
5. Soils and Crops.
6. The Problem stated.
7. Rainfall and Run-Off.
8. The Plan.
9. Estimates of Cost.
10. Conclusions and Recommendations.

DATA, MAPS, PLANS AND PROFILES.

This report is based on surveys and data furnished by the Internal Improvement Commission of Illinois and the Illinois State Geological Survey, in cooperation with the United States Geological Survey; consisting of:

- (a) The original plane-table, topography sheets, giving notes as taken in the field.
- (b) Photo-lithographic charts of the topography sheets showing surface elevations in the valley to the adjacent high land on each side of the Kaskaskia river. Contours are platted at five foot intervals.
- (c) Original field books of the surveys.
- (d) Gauge readings from date of establishment of gauges to Dec. 1, 1910.
- (e) Discharge measurements and rating tables.

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(f) Miscellaneous notes with reference to flood stages and sea level elevations.

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(f) Miscellaneous notes with reference to flood stages and sea level elevations.

(g) Maps showing location of all Illinois stream gauging stations under control of this coöperation.

A further source of information upon which this report is based is the field work, conducted from my office, consisting of:

(a) Running levels to the gauging stations along the Kaskaskia river from the nearest U. S. G. S., B. M., in order to co-ordinate each gauge with the sea level datum plane. This work was done under the direction of the United States Geological Survey.

(b) Cross-sections of the Kaskaskia river channel at intervals of about 10 miles by the course of the stream.

(c) Location of additional 1908 high water marks along the valley.

Plats are submitted herewith showing the proposed plans for reclamation, as recommended in this report. There are sixteen sheets, as follows:

Sheet No. 1. Index map showing extent of detail sheets and the location and boundary of each of the drainage units.

Sheets No. 2 to No. 11. Plans for the project, showing the following:

(a) Proposed cut-offs in the channel of the stream.

(b) Control of large tributary streams and diversion ditches for the smaller streams.

(c) Levees along the river for protection against flood.

(d) Gravity outlets.

(e) Boundary of drainage units.

(f) Cross-sections of the valley at intervals of about 10 miles by the course of the stream.

(g) Cross-sections of the river channel at intervals of about 10 miles by the course of the stream.

Sheets No. 12 and No. 13 are the profiles of the Kaskaskia river.

Sheet No. 14 is the profile of Shoal creek.

These profiles show the elevations of the bed and banks of the streams, points for reference, the proposed levee grade line, the proposed cut-offs and channel, bottom grade line through the same, and the distance in feet and in miles from the Mississippi river.

Sheet No. 15 shows the watershed or drainage area of the Kaskaskia river with its tributaries.

Sheet No. 16 is a hydrograph of the Kaskaskia river for each gauging station from the time of establishment of the gauge to Jan. 1, 1911.

All elevations in this report and on the accompanying plans are referred to sea level as determined by the U. S. G. S.

GENERAL DESCRIPTION.

The watershed of the Kaskaskia river extends in a southwesterly direction from near Champaign, Illinois, to the Mississippi river, near Chester, Illinois. The extreme length is 180 miles and the extreme width is 55 miles. The watershed is long and narrow—the ratio of length to width above Carlyle being 5.1. The area is about 5,800 square

miles, and includes a portion, or all of the following counties, viz: Champaign, Piatt, Douglas, Moultrie, Macon, Coles, Shelby, Christian, Montgomery, Fayette, Effingham, Bond, Macoupin, Madison, Marion, Clinton, St. Clair, Washington, Jefferson, Monroe, Perry and Randolph.

The principal cities located on this watershed are as follows: Sullivan, Arcola, Shelbyville, Pana, Litchfield, Hillsboro, Vandalia, Greenville, Keyesport, Lebanon, Breese, Carlyle, Centralia, Belleville, Fayetteville and New Athens.

The principal tributaries of the Kaskaskia river are: Big creek, Hurricane creek, East Fork creek, Crooked creek, Plum creek, Shoal creek, Sugar creek, Elkhorn creek, Big Mud creek and Silver creek.

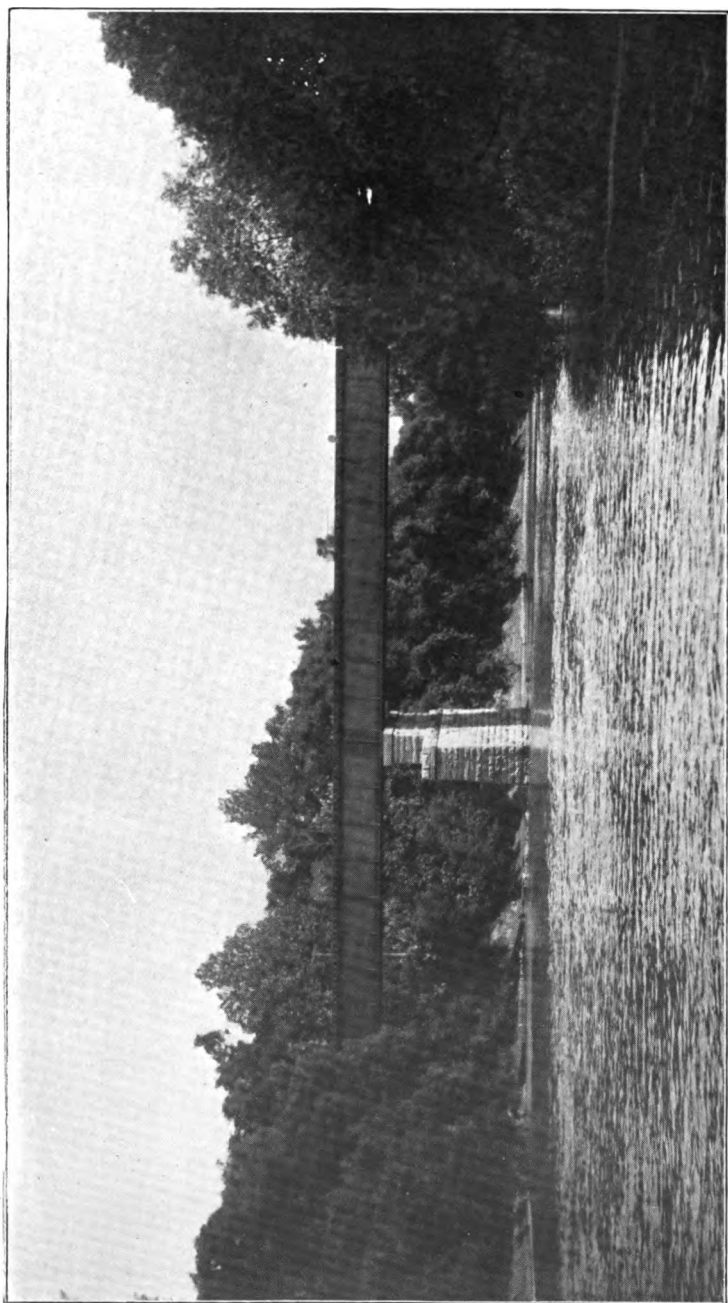
The relative locations of the tributaries of the Kaskaskia, the distance from the Mississippi river via the Kaskaskia channel to the mouth of each tributary, and the drainage area at the confluence of each tributary with the Kaskaskia are given in the following table:

KASKASKIA RIVER WATERSHED.

Name of Stream.	Miles from mouth by river route.	Drainage area—Square miles.	Total—Square miles.
Above Arcola			390
Above Shelbyville			1,040
Above Cowden bridge	196.4		1,325
Becks and Mitchell Creeks	184.9	230	1,555
Hog Creek	184.2	90	1,645
Big Creek	179.2	85	1,730
Ash Creek	175.6	40	1,770
Suck Creek	173.9	20	1,790
Ramsey Creek	172.4	115	1,905
Bear Creek	162.9	60	1,965
Vandalia Ditch (Sand, Camp, and Hickory Creek)	154.8	170	2,135
Wild Cat Ditch (Cassar, Steve and Bear Creek)	139.1	55	2,190
Hurricane Creek	135.5	200	2,390
East Fork Creek	128.1	290	2,680
Crooked Creek	89.0	490	3,170
		100	3,270
Plum Creek	77.4	40	3,310
Shoal Creek	75.4	930	4,240
Sugar Creek	73.1	175	4,415
Elkhorn Creek	62.3	100	4,515
		65	4,580
Big Mud Creek	48.3	125	4,705
Silver Creek	42.0	500	5,205
Richlands Creek	27.8	250	5,455
Creek		70	5,525
Plum Creek	14.2	110	5,635
Horse Creek	13.1	65	5,700
Watershed to mouth of river	0.0	115	5,815

The area of the lands subject to overflow in the immediate valley of the Kaskaskia river and Shoal creek, which were covered by the topographical survey and are under consideration for reclamation, is approximately 162,000 acres, or 254 square miles.

The Kaskaskia river is a very crooked stream. Its length by air line from its mouth to its source is approximately 180 miles, but following the sinuosities of the stream it is probably about 300 miles. The distance from Cowden bridge, the up-stream limit of the plans, to the mouth of the river following the median line of the overflowed valley is approximately



Constricted channel at Vandelin R. R. bridge.

122 miles; following the course of the stream is 196 miles; following the route of the channel, as proposed in these plans, is 148 miles; following a shorter route, which was estimated but not adopted, in which a much greater length of new channel would be required, is 133 miles.

The width of the valley to be reclaimed is from one-half mile wide at Cowden bridge to $3\frac{1}{2}$ miles wide at Vandalia; from Vandalia to Carlyle from 2 to 4 miles wide, and opposite Carlyle it narrows to one-half mile wide. From about 2 miles south of Carlyle the valley will average about 3 miles wide to New Athens; from New Athens to the mouth of the river the valley averages about 1 mile wide.

The portions of the Kaskaskia river and Shoal creek for which improvements are planned, as shown in this report, are located in Shelby, Fayette, Bond, Clinton, Washington, St. Clair and Monroe counties, and the principal cities upon the banks of the Kaskaskia within these counties are Vandalia, Keyesport, Carlyle, Fayetteville and New Athens.

BRIDGES.

The railroads have bridges across the Kaskaskia river at the following places, viz:

Pennsylvania Railroad at Vandalia.
 Illinois Central Railroad just south of Vandalia.
 Chicago, Burlington & Quincy Railroad at Keyesport.
 Baltimore & Ohio Southwestern Railway at Carlyle.
 Southern Railroad at Posey.
 Louisville & Nashville Railroad at New Memphis.
 Illinois Central Railroad at New Athens.
 Mobile & Ohio Railroad about 10 miles south of New Athens.
 Illinois Southern Railway.
 Missouri Pacific Railway near the mouth of the river.

BRIDGES ACROSS SHOAL CREEK ARE AS FOLLOWS:

Vandalia Railroad about 3 miles north of Baden Baden.
 Baltimore & Ohio Southwestern Railway near Breese.
 Southern Railway near Germantown.

THERE ARE HIGHWAY BRIDGES AS FOLLOWS:

ACROSS THE KASKASKIA RIVER—

In Fayette County—

Wren Bridge at S. W. Cor. Sec. 15, T. 8 N., R. 2 E., 3d P. M.
 New Bridge at S. $\frac{1}{4}$ Cor. Sec. 29, T. 8 N., R. 2 E.
 Vera Bridge in N. W. $\frac{1}{4}$ Sec. 27, T. 7 N., R. 1 E.
 Vandalia Bridge at Vandalia—
 Bridge in S. E. $\frac{1}{4}$ Sec. 5, T. 5 N., R. 1 E.
 Bridge in S. W. $\frac{1}{4}$ Sec. 17, T. 5 N., R. 1 E.
 Bridge west of Shobonier at S. $\frac{1}{4}$ Cor. S. E. $\frac{1}{4}$ Sec.
 14, T. 5 N., R. 1 W.

In Clinton County—

Bridge at Keyesport.
 Bridge at Carlyle.
 Bridge south of Carlyle in the N. W. $\frac{1}{4}$ Sec. 31,
 T. 2 N., R. 2 W.
 Covington Bridge N. W. $\frac{1}{4}$ Sec. 33, T. 1 N., R. 3 W.,
 extends into Washington county.

In St. Clair County—

Bridge at Fayetteville.

Bridge at New Athens.

ACROSS SHOAL CREEK—

*In Bond County—*Bridge in N. W. $\frac{1}{4}$ Sec. 23, T. 5 N., R. 4 W.Bridge in N. E. $\frac{1}{4}$ Sec. 35, T. 5 N., R. 4 W.Bridge in W. $\frac{1}{2}$ Sec. 12, T. 4 N., R. 4 W.Bridge in N. W. $\frac{1}{4}$ Sec. 24, T. 4 N., R. 4 W.*In Clinton County—*Bridge in E. $\frac{1}{2}$ Sec. 2, T. 3 N., R. 4 W.Bridge in N. E. $\frac{1}{4}$ Sec. 23, T. 3 N., R. 4 W.

Bridge near center Sec. 2, T. 2 N., R. 4 W.

Bridge on line between Sections 13 and 24, T. 2 N.,
R. 4 W.Bridge on line between Sections 26 and 35, T. 2 N.,
R. 4 W.Bridge in S. W. $\frac{1}{4}$ Sec. 1, T. 1 N., R. 4 W.Bridge in N. E. $\frac{1}{4}$ Sec. 15, T. 1 N., R. 4 W.Bridge in N. W. $\frac{1}{4}$ Sec. 29, T. 1 N., R. 4 W.

DRAINAGE DISTRICTS AND DITCHES.

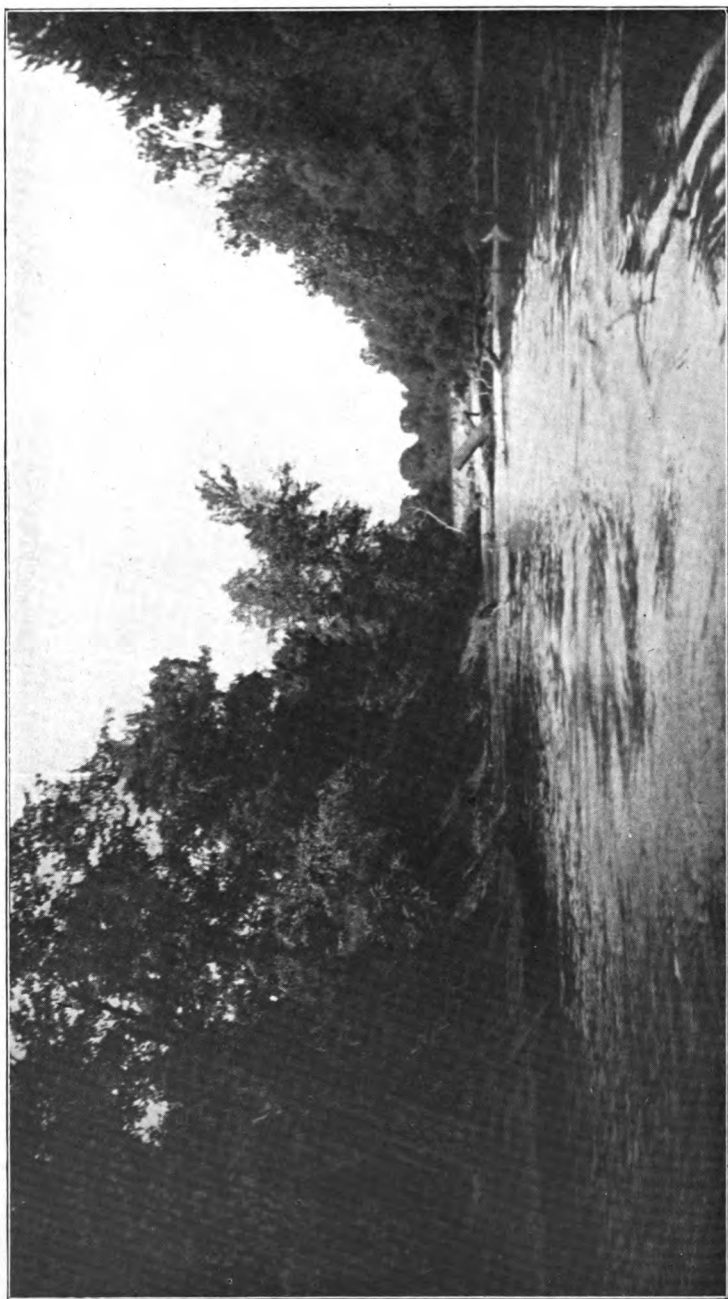
Pepper Mill Branch Drainage District on the west side of the Kaskaskia river at New Bridge, in Fayette county, township 8 north, range 2 east, contains approximately 1,750 acres. It has a main drainage ditch with several laterals, but no levee. It is subject to overflow by the Kaskaskia river.

Vandalia Drainage and Levee District, on the east side of the Kaskaskia river, has an area of approximately 13,400 acres. A levee has been constructed on the east bank of the river, connecting with the bluffs at the north end of the district and open to the river and to back water at the south end of the district. The district is provided with a number of interior drainage ditches leading to an open outlet at the south end of the district. There are a number of hill streams which flow into the drainage district. These streams are conducted into the drainage ditches of the district. The levee is built close to the river bank for a greater portion of the distance and restricts the flood channel. The levee has broken a number of times since its construction, and in 1908 and 1911 the entire district was inundated.

Pecan Island is surrounded by two arms of the Kaskaskia river and lies about $3\frac{1}{2}$ miles south of Vandalia, and contains 1,040 acres. A levee is now in process of construction to protect the island from overflow.

Fish Lake Drainage Ditch, with branches, is located along the foot of the bluff directly west of Pecan Island. This ditch is about 5 miles long and empties into the Kaskaskia river just below Pecan Island.

Wild Cat Drainage Ditch, with branches, on the east side of the Kaskaskia river just south of the highway bridge west from Shobonier, follows about midway of the bottom lands from the highway to its outlet into the Kaskaskia river just above Cox's ferry, in Fayette county, section 16, township 4 north, range 1 west.



Channel choked with driftwood,

Soper Lake Drainage Ditch, with branches, begins just south of Cox's ferry on the east side of the Kaskaskia river extending through the bottom lands to its outlet into the Kaskaskia about 2 miles northeast of Keyesport.

Santa Fé Drainage District lies on the west bank of the Kaskaskia river just south of the Louisville & Nashville Railroad, in Clinton county. This district has a small levee, not high enough for protection from high water overflow. This levee encloses about 2,500 acres. There is a ditch with branches which empties into the Kaskaskia river.

SOIL AND CROPS.

The overflowed valley of the Kaskaskia and its tributaries, like the valley of all alluvial streams, contains the elements of soil fertility in greatest abundance and will produce phenomenal crops of grains and grasses and garden truck when protected and drained.

Owing to the uncertainty of raising a crop or of harvesting, even if matured, only minor portions of the valley are under cultivation. Much of the land is still in timber. The cost of clearing is from ten to twenty dollars per acre, and unless kept in cultivation thereafter the brush and sprouts spring up and quickly cover the land with a second growth. The hazard of farming such land is so great that well-to-do tenants cannot be placed on the land and it cannot be handled without danger of disastrous losses, except in comparatively small tracts, adjacent to a farm, which will be safe, and the bottom lands handled merely on a chance that floods may not come.

THE PROBLEM.

(a) To develop a system of drainage and protection for the reclamation of the lands subject to overflow in the immediate valleys of the Kaskaskia river from Cowden bridge, about three-quarter mile north of the Shelby-Fayette county line to New Athens, and of Shoal creek from the north limit of the surveys in Bond county to its mouth.

(b) To formulate reclamation plans in such a manner as to make possible the independent development of drainage units in accordance with a general plan, which, when completed, will furnish adequate protection from overflow and thorough drainage of all of the lands.

The order of development of such a general plan of reclamation is as follows:

(1) Straightening of the channels of the Kaskaskia river and Shoal creek, and tributaries within the overflowed valley as a general improvement.

(2) Building of the levees for protection from overflow, interior ditches for the drainage of the lands within each drainage unit, and providing an adequate drainage outlet by the construction of gravity outlet channels extending a sufficient distance down the stream for a gravity outlet at all stages of the river, or by the construction of sluiceways through the levees for gravity drainage when the river is low, and pumping plants for lifting the water out of the ditches when the river is high.

NOTE—This study and these preliminary plans provide for such gravity outlet ditches as might under any circumstances be practicable. No study has been made of the detail drainage, nor of the pumping plants, which would be necessary. Approximate estimates, only, of the unit cost, per acre, for detail drainage and pumping plants will be given.

RAINFALL AND RUN-OFF.

Rainfall—The rainfall for a period of 10 years—1901 to 1910, inclusive, has been compiled for twenty stations on and adjacent to the watershed of the Kaskaskia from reports of the United States Weather Bureau. The minimum annual rainfall occurred in 1901, averaging 27.7 inches. The maximum annual rainfall occurred in 1904, averaging 48.6 inches. The average annual rainfall for the 10 years was 38.8 inches.

The rains with which we are most concerned in studying the problem of reclaiming this valley from overflow are those which follow closely upon each other. When the soil becomes saturated and the streams swollen to bank full, or overflowed, any additional rain results in a greater rate of run-off.

The river banks in all silt-bearing streams are higher than lands farther back from the river. This is due to the fact that when the river is in flood it carries sediment, the heavier and major portion of which is deposited from the water that overflows as soon as it leaves the main channel, because the velocity is reduced and the silt carrying capacity proportionately diminished. In this way the banks become higher with each succeeding overflow.

In the Kaskaskia valley the banks are from one to three feet higher than the lands lying between the river and the bluffs, and the lower land generally extends entirely across the valley to the foot of the bluff, so that a bank-full stage means practically inundation, or at least closing the outlet of the drains for the entire overflowed area.

The cross-sections of the valley platted on the detail maps, Sheets Nos. 2 to 11, inclusive, show the extent to which a bank-full stage inundates and holds back the drainage of the lands.

The most disastrous floods in the Kaskaskia valley occurred in May, 1908. At this time all the bottom lands were flooded from 3 feet to 10 feet deep. The Vandalia Levee District was inundated when the levee broke. The river was over its banks during that flood at Vandalia until May 27th, at Carlyle until June 3d, and at New Athens until about June 6th.

During 1909 the river was not so high as in 1908, but was about a bank-full stage oftener and for a greater number of days. At Vandalia it was out about ten days in February, four days in March, twenty-two days in April, four days in May; at bank-full stage three times in June, and out of banks ten days in July. In 1910 the conditions were about equally as bad for raising crops. The river was out of its banks in January, February, March, May and July.

The highest floods have occurred in the following years, viz, 1875, 1882, 1898, 1907, 1908 and 1911.

The river stages as read under the direction of the United States Geological Survey are platted on Sheet No. 16 for Arcola, Shelbyville,

Vandalia, Carlyle and New Athens. The hydrographs show very clearly how the stage of the river affects the drainage of the land and how utterly useless it is to undertake to farm the lands without levee protection and thorough drainage.

The detail records of the rainfall, at the stations on the Kaskaskia watershed, that produced the flood in May, 1908, furnish most interesting data and as they were compiled in the study of this problem will be reproduced here.

TABLE OF RAINFALL.

Stations.	May—1908.														
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Urbana.....	.04	....	.59	1.18	0.36	0.31	1.74	T	....	....	1.29	....	.49	.13	....
Sullivan.....	.42	....	.40	1.95	2.20	.24	1.56	.06	....	....	.68	....	.34	.04	....
Tuscola.....	T	.05	....	1.41	1.34	.18	1.74	.51	.01	....	.09	.41	.12	.07	....
Windsor.....	.09	....	.49	4.10	3.50	.37	1.50	.05	....	....	1.00	....	.18	.04	....
Pana.....	T	....	.67	.96	2.36	.87	1.20	.09	....	....	.91	....	.27	.09	....
Greenville.....	T	....	.53	.04	1.31	2.70	.48	....	....	....	.23	....	.20	.16	....
Carlyle.....	....	....	.25	.35	2.00	1.75	.70	....	....	.15	....	....	.10	.20	....
Bement.....	.06	T	.17	1.36	.75	.11	1.50	.07	.02	....	.71	T	.76	.05	....
Averages.....	0.09	0.03	.44	1.42	1.73	0.82	1.30	0.13	0.02	0.15	0.70	.20	0.32	.10	....

A diagram showing the average rainfall monthly for twenty stations on and adjacent to the Kaskaskia watershed has been prepared for the years 1901 to 1910, inclusive. The year 1901 was the last of the long series of comparatively dry years. The rainfall in no month of that year exceeded the normal, and for the year was 11.6 inches, or 30 per cent below normal. The following years, however, show a much greater rainfall and, consequently, higher river stages. We have not the continuous gauge readings prior to 1908, so the rainfall records are the best data we have to base a judgment on as to the drainage conditions prevailing in the valley.

For more detailed data regarding rainfall and stream gaugings, reference is hereby made to the report of the Internal Improvement Commission of Illinois on "Surface Water Supply of Illinois—Central and Southern Portions—1908-1910."

RUN-OFF.

Gauging Stations—Gauging stations were established by the United States Geological Survey and the Internal Improvement Commission of Illinois in 1908 and 1909. Readings of the gauges have been taken daily and a number of discharge measurements taken since that time. In May, 1908, the most serious flood within the memory of the people then living in the Kaskaskia valley, occurred. All the low lands in the valley were flooded and the discharge at maximum flood stage, and at bank-full flood stage is given in the accompanying table, based upon the rating tables, as prepared by the United States Geological Survey.

The flood data for the 1908 high water in the Kaskaskia river, Shoal creek and Silver creek at the gauging stations, established by the U. S. G. S. in this coöperation, are shown in the following table:

DISCHARGES—1908 FLOOD AND BANK STAGE.

Gauging station.	Distance from mouth miles.	Drainage area square miles.	Gauge height.	Discharge—1908 Flood.		Gauge height.	Discharge Bank Stage.		Sea level elevation "O" of gauge.
				Cubic feet per second.	Cubic feet per second per square mile.		Cubic feet per second.	Cubic feet per second per square mile.	
KASKASKIA RIVER.									
New Athens.....	41.6	5200	33.2	54440	10.45	20.0	10330	1.99	390.02
Carlyle.....	105.6	2705	30.8	19046	7.37	20.0	4270	1.59	403.22
Vandalia.....	160.8	2000	21.9	8070	*4.03	15.0	4680	2.32	456.23
Shelbyville.....	†(215.)	1040	25.8	10580	10.18	14.0	3650	3.51	531.62
Arcola.....	†(260.)	390	17.3	3868	9.92	9.3	1034	2.65	627.00
SHOAL CREEK.									
Breese.....	19.9	775	†22	10000	12.90	16.5	3100	4.00	412.40
SILVER CREEK.									
Lebanon.....	†(36)	500	15.9	5240	10.48	12.0	1240	2.48	416.44

* The Vandalia Levee District levee broke May 6, 1908. Only part of flood passed through the measured cross-section.

† Flood in 1907.

‡ Distances in parenthesis, thus: (36) are estimated from general map, as the topographical surveys did not extend that far.

The maximum rate of discharge in cubic feet, per second, per square mile, based upon the rating tables as furnished by the U. S. G. S., was as follows:

At New Athens	10.45	Sec. Ft., Per Sq. Mile
Carlyle	7.37	Sec. Ft., Per Sq. Mile
Vandalia	* 4.83	Sec. Ft., Per Sq. Mile
Shelbyville	10.18	Sec. Ft., Per Sq. Mile
Arcola	9.92	Sec. Ft., Per Sq. Mile

NOTE—At Vandalia the levees built on the east bank of the river for a distance of about 10 miles above Vandalia held the water until May 6, 1908, when the levee broke and a large portion of the flow then ran out through the district and through a trestle in the railroad track, about one mile east of the bridge, so that probably not more than one-half of the maximum discharge passed through the measured cross-section of this gauging station, the remainder passing through the break in the levee and trestle in the bridge.

On Shoal creek a flood in 1907 measured 12.9 cubic feet, per second, per square mile, at Breese. On Silver creek a flood in 1908 measured 10.48 cubic feet, per second, per square mile, at Lebanon.

This measured rate of run-off is very much less per square mile than has been observed under similar rainfall conditions in similar territory. This has led to an extensive investigation of the rate of run-off necessary for which provision must be made when the bottom lands within the Kaskaskia valley shall be leveed against overflow and no longer available for the storage of the flood waters which come from the adjacent hills and higher lands, and must be carried directly through the channels and between the levees substantially in the time in which it reaches the valley, instead of prolonging the period of high water for a number of days.

A large number of flood discharge observations have been collected and published by the United States Geological Survey. Civil engineers in general practice and on railroad work have collected a great deal of data on flood discharges from areas of various sizes, and much of this data has been available to the engineering profession through government and engineering society publications. A number of formulas have been suggested, based upon discharge measurements of various areas of watershed. Resort was had to the consideration of the result of these investigations by engineers; among the principal formulas are to be noted in particular the following forms in which "Q" is the total discharge in cubic feet, per second, from the given area "M" in square miles, and "C" is a factor determined by experience:

$$\text{No. 1. } Q = C \sqrt{M}$$

(Proposed by Mr. Frizzell from experience with streams in north-eastern portion of the United States.)

$$\text{No. 2. } Q = C \sqrt[3]{M^2}$$

(Proposed by Lyman E. Cooley from observation of streams in the Mississippi valley in the vicinity of St. Louis.)

No. 3. $Q = C \sqrt[4]{M^3}$ (Proposed by A. N. Talbot, which is an adaptation of the well known Berkli-Ziegler Formula.)

No. 4. $Q = C \sqrt[6]{M^5}$ (Proposed by J. W. Fanning.)

No. 5. $Q = M \frac{3000}{3+2\sqrt{M}}$ (Proposed by Geo. H. Bremner, engineer, and used by the C. B. & Q. R. R. for waterway openings.)

No. 6. $Q = M \left\{ \frac{46790}{M+320} + 15 \right\}$ (Proposed by E. C. Murphy of the U. S. Geological Survey for streams in the northeastern portion of the United States.)

The ordinary and usual coefficients, as used in the different formulas by the authors, are as follows:

For Formula No. 1, $C =$ To be determined by experience for the particular area or by similarity of condition.

For Formula No. 2, $C = 180$ to 200 .

For Formula No. 3, $C = 500$ for areas less than 200 square miles.

For Formula No. 4, $C = 200$.

Solving the value of " C " for the measured discharge of the Kaskaskia river, assuming that 10 cubic feet, per second, per square mile, represented the approximate average of the conditions for $1,000$ square miles, we find the following values of " C ":

For Equation No. 1, $C = 316$.

For Equation No. 2, $C = 100$.

For Equation No. 3, $C = 63$.

For purpose of comparison we have platted the various formulas in the form of curves to a uniform scale, and we find that within a range of from 250 square miles to $5,000$ square miles, the Murphy formula and the Bremner formula correspond very closely and give very much larger quantities than either of the other formulas. The Bremner formula for $2,700$ square miles gives a rate of 28 cubic feet, per second, per square mile. The Murphy formula for $2,700$ square miles gives a rate of 30 cubic feet per square mile. If the coefficient " C " is solved for Formula No. 1, so as to correspond with the Bremner formula for the area of $5,000$ square miles, it follows very closely the Bremner formula throughout its entire range and does not deviate from it sufficiently to make any material difference until the area is reduced to about 50 square miles, after which the quantity derived from Formula No. 1, is in excess of that derived from the Bremner formula.

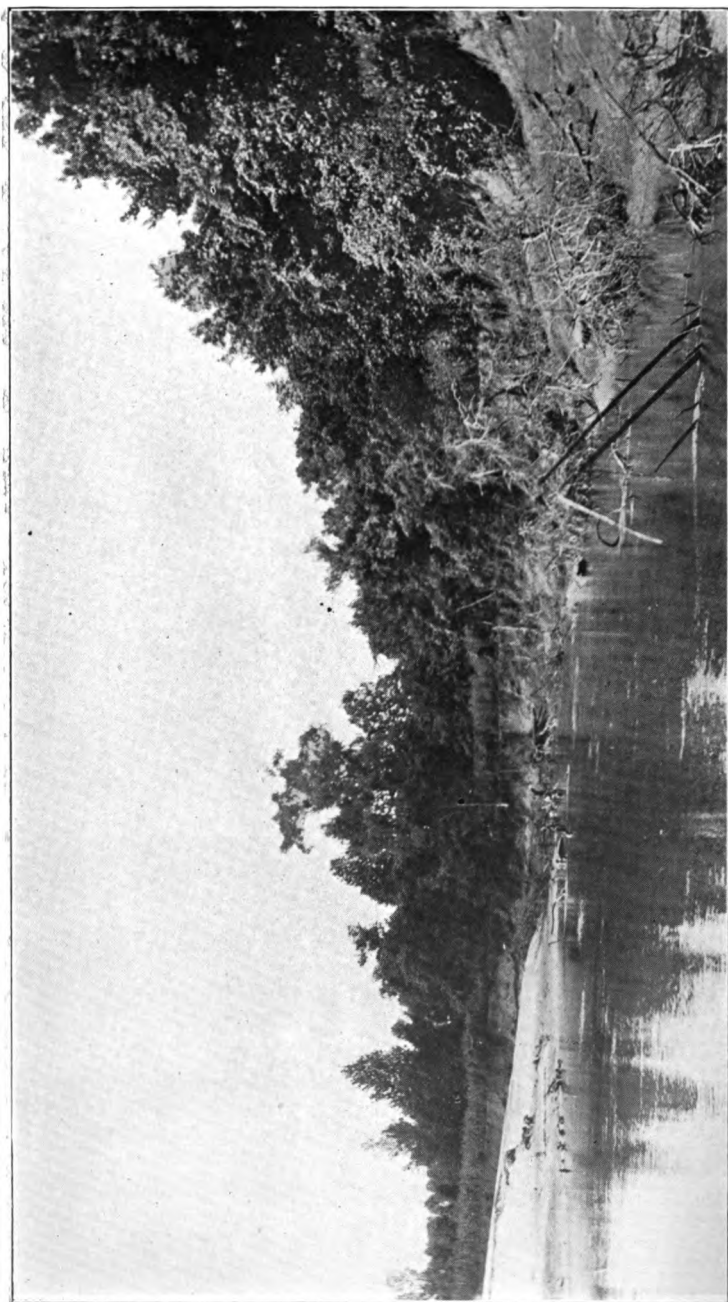
These values of " C " and the corresponding values of " Q " are so much less than the observed and recommended values by the authorities above quoted that we have undertaken a detailed study of the effect of the storage in the overflow of the Kaskaskia valley above Carlyle. The plans for the drainage improvements divide this area into a number of drain-

age units, as shown upon the maps. The total overflowed area from Cowden Bridge to Carlyle was 67,550 acres at high water in May, 1908. For the purpose of studying this storage effect we measured the area submerged within each drainage unit at high water, and at each foot below high water until the river had receded into its banks. From these measurements of area we computed the acre-feet of water in storage within the valley each day during the period of the flood, from the 3d to the 15th of May, 1908, inclusive. The results of the computations of the amount of water in storage in the valley each day, combined with the amount of the measured discharge, based upon the stage of the river and the rating table furnished by the United States Geological Survey, should give the total rate at which the flood waters entered the overflowed portion of the valley of the Kaskaskia river, which was approximately the rate at which it must be carried through the valley when the storage shall have been eliminated by the construction of levees.

The areas of submerged lands in each drainage unit, and between the drainage units, between New Athens and Cowden Bridge at high water of 1908, and at each foot below high water; and the amount of water in storage (measured in acre-feet) each day of the flood period from May 3d to 15th, inclusive, between Carlyle and Cowden Bridge, are shown in the following tables:

ACRES SUBMERGED—COWDEN BRIDGE TO CARLYLE.

District.	H. W.	-1.	-2.	-3.	-4.	-5.	-6.	-7.	-8.	-9.	-10.	-11.	-12.	-13.	-14.	-15.
Cowden Bridge to Fanny Branch	612	472	250	000	000	235	135	55	000							
Fanny Branch to No. 27	1,075	785	498	225	335	1,762	1,340	890	560	310	126	000				
Wren Bridge North	2,749	650	545	440	2,030	1,975	1,250	708	425	240	100	000				
28	4,844	4,375	2,628	2,925	2,475	1,460	1,190	930	660	391	160	000				
27	2,402	2,325	2,185	1,970	1,726	1,460	1,190	930	660	391	160	000				
26	1,306	1,190	1,190	1,070	915	628	355	180	60	000						
25	1,265	1,215	1,190	1,070	925	755	553	285	105	000						
24	1,404	1,330	1,215	1,075	925	755	553	285	105	000						
23	1,510	1,430	1,420	1,343	1,240	1,065	880	650	418	180	30	000				
22	4,946	4,750	4,350	3,854	3,350	2,850	2,340	1,825	1,315	830	420	125	000			
21	5,890	5,700	5,500	5,280	5,070	4,805	4,475	4,075	3,550	2,925	2,066	850	250	60	000	
North of Railroad	7,200	7,080	6,780	6,400	5,900	5,205	4,225	3,250	2,250	1,370	716	280	50	000		
South of Railroad	7,75	74	74	73	72	70	67	61								
Between Vandalia and the River	123	121	118	115	110	98	000									
From 22 North to Vandalia	3,882	3,720	3,450	3,100	2,650	2,100	1,575	1,080	660	240	38	000				
19	5,250	4,810	4,280	3,760	3,230	2,710	2,180	1,650	1,150	773	475	250	80	000		
18	2,578	2,500	2,340	2,110	1,809	1,490	1,170	860	620	418	250	120	35	000		
Upper Part—																
17	2,720	2,640	2,200	1,702	1,370	1,070	780	500	238	000						
Lower Part—																
16	4,334	4,140	3,750	3,220	2,643	2,050	1,520	1,080	650	323	100	000				
15	2,652	2,620	2,550	2,460	2,350	2,201	1,970	1,640	1,280	880	465	80	000			
From Carlyle North to 16	894	880	850	810	770	706	645	570	490	370	236	110	30	000		
15	10,334	9,750	9,124	8,525	7,900	7,300	6,700	6,063	5,450	4,800	3,920	2,875	1,850	925	300	000
Total	67,550	64,157	58,787	52,737	46,870	40,565	33,350	26,322	19,811	14,050	9,102	4,090	2,285	985	300	000



Caving bank on outside of bend, sand bar inside and drift in channel.

ACRES SUBMERGED—CARLYLE TO NEW ATHENS.

District.	H. W.	-1.	-2.	-3.	-4.	-5.	-6.	-7.	-8.	-9.	-10.	-11.
14.....	717	710	680	638	575	505	440	370	307	235	170	110
13.....	2,215	2,185	2,152	2,115	2,070	2,020	1,940	1,806	1,540	1,170	770	390
12.....	612	610	601	590	578	565	545	512	578	436	388	325
11.....	2,026	2,015	2,000	1,970	1,908	1,810	1,690	1,560	1,420	1,239	920	230
10.....	8,357	8,320	8,250	8,130	7,875	7,450	6,900	6,230	5,400	4,415	2,900	1,600
9.....	4,238	4,130	3,980	3,900	3,565	3,200	2,600	1,850	1,000	208	000	.....
South of	290	275	255	230	195	135	68	24	000	.....	.....	.....
8.....	9,790	9,680	9,550	9,050	8,000	6,700	5,200	3,973	2,950	2,150	1,500	950
7.....	5,592	5,250	4,850	4,445	3,930	3,350	2,620	1,940	1,385	900	710	530
6.....	4,403	4,360	4,270	4,110	3,920	3,600	3,400	2,800	2,250	1,620	1,070	700
5.....	4,071	3,640	3,380	3,205	3,100	3,020	2,950	2,870	2,753	2,580	2,350	2,120
4.....	9,043	8,700	8,373	8,000	7,640	7,250	6,900	6,520	5,950	5,200	4,200	3,260
3.....	7,492	7,400	7,350	7,250	7,160	7,081	6,330	5,940	5,530	5,106	4,800	4,450
North of Fayetteville	645	640	635	630	628	624	618	615	610	605	602	595
2.....	4,311	4,220	4,150	4,060	3,970	3,854	3,780	3,620	3,400	3,150	2,855	2,360
1.....	1,471	1,445	1,415	1,385	1,345	1,288	1,200	1,110	1,010	900	745	550
Total.....	65,273	63,580	61,891	59,603	56,499	52,492	47,181	41,740	35,983	29,973	23,980	18,170

ACRES SUBMERGED—CARLYLE TO NEW ATHENS.

District.	-12.	-13.	-14.	-15.	-16.	-17.	-18.	-19.	-20.	-21.	-22.
14.....	60	20									
13.....	128	000									
12.....	257	140									
11.....	000										
10.....	800	270									
9.....											
South of 9.....											
8.....	530	200	000								
7.....	380	245	130	60	000						
6.....	400	168	000								
5.....	1,820	1,372	420	000							
4.....	2,589	2,050	1,050		900	555	270	100	000		
3.....	4,120	3,800	3,482	1,250	1,800	1,000	500	250	000		
North of Fayetteville.....	590	588	582	2,800	1,550	495	420	320	190	95	000
1.....	1,730	920	450	580	180	150	110	75	40	000	
2.....	330	185	90	25	000						
Total.....	13,734	9,958	6,804	4,935	3,430	2,200	1,300	745	230	95	000

INCREASE AND DECREASE OF STORAGE—COWDEN BRIDGE TO VANDALIA.

May, 1908.	Acre feet by districts and tracts not included in districts.										Totals.		
	Fanny Branch to Cowden Bridge.	District 27 to Fanny Branch.	When Bridge North.	28.	27.	26.	25.	24.	23.	Between Vandalia and river.	21 part north of R. R.	Increase per day.	In storage.
3-4.....	.....	.....	123	1,441	2,068	881	150	3	657	.....	.....	5,353	5,353
4-5.....	.....	75	650	3,531	5,130	3,180	1,269	843	2,340	.....	.....	17,163	22,516
5-6.....	486	1,288	1,996	10,442	13,561	10,146	4,896	6,040	6,219	.....	.....	55,508	78,024
6-7.....	335	728	952	4,813	6,704	5,061	2,273	3,114	2,945	.....	.....	4,492	82,516
7-8.....	877	1,410	952	2,620	6,224	1,544	1,242	475	1,302	.....	*31,610	19,954	102,470
8-9.....	785	1,287	952	3,366	6,224	2,383	1,481	-1,145	1,724	.....	.....	24,851	77,619
9-10.....	243	668	747	2,582	4,585	1,759	1,341	-812	1,492	.....	.....	18,836	58,783
10-11.....	.....	90	335	1,700	2,271	1,400	1,781	-629	881	.....	.....	11,819	46,964
11-12.....	.....	175	175	982	1,271	637	319	323	595	.....	.....	-1,964	40,670
12-13.....	.....	83	374	374	705	153	154	-38	114	.....	.....	-2,115	38,555
13-14.....	.....	159	885	885	1,275	723	418	-324	550	.....	.....	-6,270	32,285
14-15.....	.....	123	785	785	1,054	656	252	-253	499	.....	.....	-5,697	26,588
	1,363	2,773	3,721	18,084	27,013	15,751	7,557	7,361	10,518	551	34,896	102,470	
	-1,363	-2,773	-3,536	-15,487	-24,089	-12,772	-7,010	-6,638	-8,800	-443	-20,080	-75,882	

* Levee broke.

— When negative sign precedes a number it indicates a decrease instead of an increase.

INCREASE AND DECREASE OF STORAGE—VANDALIA TO CARLYLE.

Acre feet by districts and tracts not included in districts.											
May 1908.	From 22 north to Vandalia.	22.	21 part south of R. R.	20.	19.	18.	Upper part 17.	Lower part 17.	16.	Carlyle north to 16.	15.
3-4.....	.....	3,006	.....	777	2,361	519	119	400	384	-36	900
4-5.....	153	6,164	.....	6,242	4,360	1,418	654	1,256	1,237	242	5,327
5-6.....	470	13,866	.....	7,828	10,485	1,971	2,517	4,191	2,530	823	11,035
6-7.....	61	473	*41,401	1,338	827	1,383	1,181	2,583	2,462	958	9,884
7-8.....	.....	5,321	4,298	6,966	7,821	5,860	5,767	10,099	8,161	2,960	28,960
8-9.....	98	-1,963	-3,011	-3,073	0	1,533	1,618	3,405	2,898	1,323	12,939
9-10.....	84	-3,358	-3,051	-3,064	-4,059	-2,038	-2,150	-3,405	-2,854	-1,082	10,463
10-11.....	83	-3,640	-3,284	-3,284	-3,762	-2,212	-2,501	-4,019	-3,006	-1,151	11,453
11-12.....	58	-2,550	-3,005	-2,729	-3,424	-2,507	-2,050	-3,822	-3,006	-1,151	11,453
12-13.....	0	-810	-2,300	-1,252	-1,199	-1,046	-1,004	-1,867	-1,924	-621	6,320
13-14.....	57	-1,940	-2,907	-1,805	-2,255	-1,341	-881	-1,911	-1,619	-363	-3,353
14-15.....	34	-1,461	-2,480	-1,382	-1,398	-865	-497	-1,189	-1,111	-413	-4,380
.....	684	28,357	45,699	20,314	25,854	12,684	11,856	21,834	18,692	6,342	69,045
.....	-475	-16,195	-24,410	-13,536	-16,097	-10,009	-9,083	-16,313	-12,625	-4,556	-46,779

* Levee broke.
 — When negative sign precedes a number it indicates a decrease instead of increase.

INCREASE AND DECREASE OF STORAGE—VANDALIA TO CARLYLE.

May—1908.	Totals.		Totals— Cowden Bridge to Carlyle.	
	Increase per day.	In storage.	Increase per day.	In storage.
3-4.....	8,430	8,430	13,783	13,783
4-5.....	23,453	31,883	40,616	54,399
5-6.....	56,716	88,599	112,224	166,623
6-7.....	61,503	150,102	65,995	232,618
7-8.....	86,300	236,402	106,254	338,872
8-9.....	17,417	253,819	-7,434	331,438
9-10.....	-34,668	219,151	-53,504	277,934
10-11.....	-38,666	180,485	-50,485	227,449
11-12.....	-36,135	144,350	-42,429	185,020
12-13.....	-16,573	127,777	-18,688	166,332
13-14.....	-21,194	106,593	-27,454	138,878
14-15.....	-15,210	91,383	-20,907	117,971
	253,419 -162,436			

— When negative sign precedes a number it indicates a decrease instead of increase.

These computations show that the maximum rate at which the water was entering the overflowed valley between Carlyle and Cowden Bridge from the entire watershed of 2,700 square miles above Carlyle to have been approximately at the rate of 25 cubic feet, per second, per square mile, which is equivalent to about one inch of rainfall in 24 hours.

From the foregoing we find that the rate of run-off from the 2,700 square miles above Carlyle corresponds very nearly to the quantities given in the Bremner and Murphy formulas, that is, our estimated rate of 25 cubic feet, per second, is slightly less than the amounts given by these formulas. We decided that the form of the Murphy formula would probably best represent the variations in rate of run-off per square mile from the various portions of the Kaskaskia valley. We, therefore, made a determination of constants for the equation which would follow substantially the form of the Murphy curve, and would give 25 cubic feet, per second, per square mile, with an area of 2,700 square miles. This

30000

formula is $q = \frac{30000}{M+200} + 15$. This formula (hereinafter referred to

as No. 7) was platted into a curve and used to determine the rate of run-off as a basis for computing the dimensions of the flood-ways for the main stream and its tributaries.

The discharge measurements show an average rate of run-off of about 10 cubic feet, per second, per square mile, for seven gauging stations of the Kaskaskia and its tributaries. The channel of the Kaskaskia river and its principal tributaries, when running bank-full, have a capacity of about $3\frac{1}{3}$ cubic feet, per second, per square mile. From this we observed that natural streams of this watershed carrying 1,000 square miles, or more, have constructed for themselves natural channels of a capacity of about $3\frac{1}{3}$ cubic feet, per second, per square mile. For determining the quantity of water to be carried within the channels of the

smaller streams, we used the formula $Q = 33 \sqrt[8]{M^2}$. This formula

when solved for an area of 1,000 square miles gives $3\frac{1}{3}$ cubic feet, per second, per square mile. A curve was made from this formula and the estimates for the channels for the tributaries of 500 square miles, or less, were based upon this curve.

Levees to be constructed along the banks of the main stream and the tributaries are to be of a height and distance apart to provide a flood-way between the levees and in the channel, which will carry the quantity of water as shown by the curve which was derived from our formula

$$q = \frac{30000}{M+200} + 15.$$

The levees will be built 3 feet above the flood line, as estimated by the above procedure.

On the diagrams prepared for the comparisons of the various forms of curve to represent the rate of run-off, per square mile, we have platted all the forms herein considered with the coefficients suggested by the authors, and upon various other assumptions, as follows:

Formula No. 1—The value of "C" = 316 was determined by taking $q=10$ cubic feet, per second, per square mile, for 1,000 square miles, the observed rate of run-off in the Kaskaskia watershed. The coefficient "C" for Formulas No. 2 and No. 3 were solved on the same basis.

Formulas No. 1-A and No. 2-B, the coefficient "C" for each were solved so as to give a discharge of 25 cubic feet, per second, per square mile, for an area of 2,700 square miles, which is our computed rate at Carlyle. (The coefficient $C=33$ was solved so as to give 3.33 cubic feet, per second, per square mile, for an area of 1,000 square miles.)

Formula No. 2-A— $C=200$ is the author's coefficient.

Formulas Nos. 4, 5 and 6, are platted as given by their authors.

Formula No. 7 is the form of that used by Murphy with such a determination of the constants as will show a run-off of 175 cubic feet, per second, per square mile, for a drainage area of one square mile; a run-off of 58 cubic feet, per second, per square mile, for a drainage area of 500 square miles, and a run-off of 25 cubic feet, per second, per square mile, for a drainage area of 2,700 square miles. This curve follows substantially the Murphy Curve No. 6, and the Frizzell Curve No. 1-A, except that for areas of less than 50 square miles the Frizzell formula gives much greater values than either No. 6 or No. 7.

FORMULAS USED.

Formula No. 2-C was used for the quantities to be carried by the excavated channels for the tributary streams.

Formula No. 7 was used for the quantities of water to be carried in the flood-ways of the main and tributary streams.

The channel for the cut-offs on the Kaskaskia river and Shoal creek straightening were figured on a basis of carrying 3.33 cubic feet, per second, per square mile, except that when the computed bottom width of the channel for the Kaskaskia reached 100 feet, no further increase of width was made because of the increased cost of construction.

The diagrams or curves platted for comparison from the formulas used extensively by engineers to determine the flood discharge from streams, and the formulas derived for use in this investigation are here inserted.

In computing the area of the channels and flood-ways the Chezy formula was used— $V = C \sqrt{R S}$ in which V = average velocity in feet per second for the entire cross-section, S = sine of the slope and R = hydraulic means radius.

Kutter's formula was used for determining the value of "C" using $n = .025$.

For determining the velocity of flow the flood-way was divided into two parts, as follows: (1) The channel proper, including the area of flood-way immediately above and between the lines of the slopes projected to the flood plane. (2) The combined areas between this prism and the levees on both sides. "R" was determined as follows: (1) For the central portion by dividing the area of the bank-full stage by the wetted-perimeter thereof, and adding to the quotient the depth from bank-full to the flood stage. (2) For the flood-way outside of this prism by dividing the combined areas on both sides of the channel prism by the length of the combined bottom width, plus the two side slopes.

THE PLAN.

Reviewing briefly the general conditions of the overflowed portion of the Kaskaskia valley, we find that from the mouth of the Kaskaskia to New Athens the overflowed area is very narrow, ranging from one-quarter to one mile in width, averaging probably not to exceed one-half mile. From New Athens to Carlyle the width runs from a minimum of one and one-half miles to a maximum of about four miles in width. From Carlyle to Vandalia the width is almost uniformly between two and one-half and three and one-half miles. From Vandalia to within about six miles of Cowden Bridge the width is from two to three miles, and thence to Cowden Bridge the width is from one-half mile to one mile. The width of the overflowed valley of Shoal creek, from the Kaskaskia valley to the limit of the survey, varies generally from one-half to one and one-half miles; there are short distances where it is somewhat wider, and other stretches where it narrows to less than one-quarter mile. Altogether this furnishes a large tract of the most fertile land in the State, which is now practically useless and looks attractive for reclamation.

There is a total of 140,735 acres in the Kaskaskia valley, as shown upon the accompanying plans, to be reclaimed and about 6,000 acres of detached area for which no provision is made. There are about 15,000 acres of overflowed land below New Athens for which no plans for protection have been provided; there are about 18,000 acres of overflowed lands in the Shoal creek bottoms.

The depth of the natural channel of the Kaskaskia river, and of Shoal creek, is such that if an ordinary low water stage should be maintained

in these streams complete drainage by ditching alone could be furnished to all of the overflowed lands. The problem then becomes one of finding and substituting plans by which the equivalent of an ordinary low water stage outlet may be provided. This might be accomplished by the construction of a larger and deeper channel, sufficient to carry all the floods within the channel below the banks. Such an undertaking would require the expenditure of such a vast sum of money it is apparent that the benefits would not be equal to the cost and, therefore, this suggestion would not receive serious consideration, as any plan to be adopted must offer financial and sanitary benefits equal to or greater than the cost.

The present channel of the stream is very crooked, frequently passing partially or entirely across the overflowed valley with numerous bends and loops. If the channel were shorter there would be less obstruction to the flow of the water, and with the greater velocity and carrying capacity, would be very materially increased so that flooding of the lands would not be so frequent. The amount of straightening of the channel, which would be profitable and economical, becomes one of the essential elements of our investigation. The present length of the channel and the median route, or shortest possible route, were first determined. We find that the distance from the Mississippi river to Cowden Bridge is 196.4 miles by the channel route, and by the median route 122.1 miles. For the improvements two routes were considered and estimated. The shorter route, which was not adopted, measured 132.6 miles, or only 10½ miles more than the median route. 88.3 miles, or 66.5% of this route would be in the old channel, and 44.3 miles, or 33½% in cut-offs. The longer route, which has been adopted as the basis of this report, has a total length of 148.1 miles, of which 130.1 miles, or 88% is old channel, and 18 miles, or 12%, is new channel. In comparison, therefore, there would be about two and one-half times as many miles of cut-offs in the shorter route as there would be in the longer route.

Following is a table of the comparison of the lengths of the routes as above described:

COMPARISON OF ROUTES—LENGTHS.

Locality.	Present river.	Median route.	Short route (not adopted)	Proposed route.
Mississippi River—				
New Athens.....	41.6	28.6	32.6	34.
Carlyle.....	64.0	39.7	42.4	49.5
Vandalia.....	55.2	30.1	33.0	37.1
Cowden bridge.....	35.6	23.7	24.6	26.9
Total miles.....	196.4	122.1	132.6	148.1

LEVELS.

In the description of the rainfall and run-off the basis for computing the dimensions of the channels in the cut-offs and the floodways between the levees has been described. These cut-offs and the levees have been

estimated upon that basis. A comparison of the quantities in the short route (not adopted) and the route as adopted, shows that the excavation in the cut-offs for the short route is approximately 17,000,000 yards, and for the route adopted is 6,750,000 yards; the main levee required for the short route is approximately 14,500,000 yards, and for the route adopted 16,500,000 yards, a net combined saving in favor of the adopted route of approximately 8,000,000 cubic yards of excavation.

LEVEE SPECIFICATIONS.

The soil of which the levees are to be built is a heavy river silt or clay and will form a strong and fairly impervious levee. The duration of the floods or extreme high water stages are short so that the levees will not ordinarily become saturated more than a few feet from the surface.

The estimates for levees have, therefore, been made on the basis of a top width of 3 feet and combined side slopes of 4 horizontal to 1 vertical with either $2\frac{1}{2}$ to 1 on the water side and $1\frac{1}{2}$ to 1 on the land side, or equal slopes on both sides, as may be later determined. The levee base must be cleared of all vegetation and stumps and large roots removed. For levees more than 10 feet high exploration trenches, or muck ditches about 3 feet deep and 4 feet to 6 feet wide should be dug along the center line of the levee, and the surface of the ground on which the levee is built broken with plow to unite the fill to the natural surface in such a manner as to prevent seepage from following the surface line. The exploration trench, or muck ditch, may be filled as any other portion of the levee.

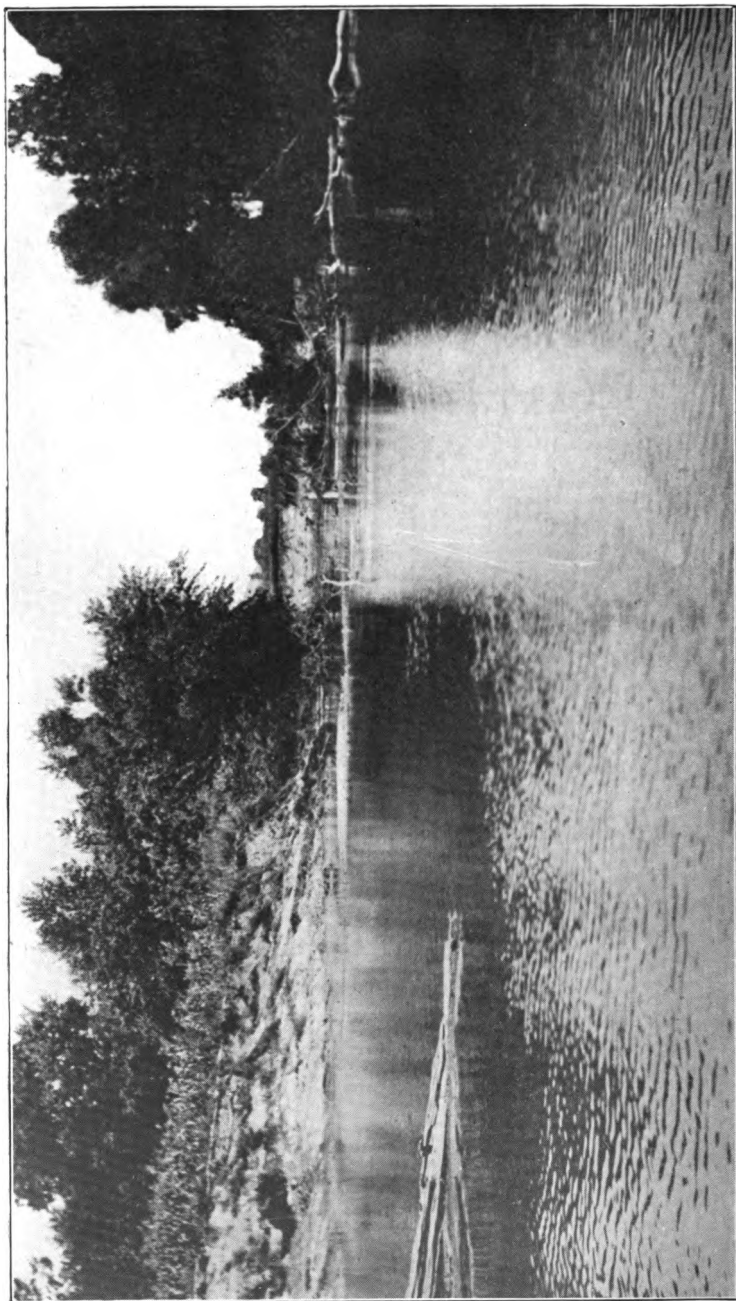
The flood-way between levees must be cleared of timber and brush, with stumps cut low and kept clear of undergrowth by pasturing or cutting from year to year so as to furnish a free channel for the floods that may come at any season of the year.

The levees are designed to be built 3 feet above the estimated flood height in the flood-way and are considered safe for all floods.

The following is a table of the comparison of distances and quantities of excavation for cut-offs and fills for levee of the short route, and the route as adopted:

COMPARISON OF ROUTES—QUANTITIES.

Location.	Short Route (Not Adopted.)				Proposed Route.			
	Length in Miles.		Cubic Yards.		Length in Miles.		Cubic Yards.	
	Cut-offs.	Old channel used.	Total.	Cut-offs.	River levee.	Cut-offs.	River levee.	Cut-offs.
Mississippi River to New Athens.....	3.7	28.9	32.6	1.9	32.7	34.6	618,300	9,437,200
New Athens to Carlyle.....	16.9	25.5	42.4	5.3	44.2	49.5	2,533,000	4,938,500
Carlyle to Vandalia.....	14.2	13.3	33.0	6.6	30.5	37.1	2,751,900	2,090,600
Vandalia to Cowden Bridge.....	9.5	15.1	24.6	4.2	22.7	26.9	961,900	16,466,300
Totals.....	44.3	88.3	132.6	18.0	130.1	148.1	6,865,000	16,466,300
Percents.....	33.5	66.5	100	12	88	100	.....	.....



Bend choked with driftwood.

The length of the old channel abandoned is 108.1 miles for the short route, and 66.3 miles for the proposed route. The short route would use 45% and the adopted route would use 66½% of the length of the present channel.

The detailed location, lengths and numbers, bottom widths, channel grades and other data of the cut-offs for the Kaskaskia river channels, and the Shoal creek channel are given in the following tables:

PROPOSED KASKASKIA RIVER GRADES—CUT-OFFS.

Locality.	Station.	Length, miles.	Cut-off numbers.	Bottom width.	Channel grade elevation	Bottom grade slope.
		17.1	<i>Inclusive.</i>			
1 mile below M. & O. R.	90	17.5	1-8	100'	355.0 }	.00005
New Athens.....	182.5	7.8	9-13	100'	360.0 }	.00007
Fayetteville.....	233.5	8.5	14-18	100'	363.0	.00016
Elkhorn Creek.....	268.5	18.5	19-33	100'	370.0	.00025
Covington Bridge.....	366.5	14.7	34-41	100'	395.0	.00017
Carlyle.....	444.0	12.9	42-54	100'	408.0	.00016
Keyesport.....	512.0	24.2	55-62	95'	419.0	.00026
Hurricane Creek.....			63-83	85'		
Vandalia.....	640.0	13.0	84-92	65'	452.0	.00036
Linn Creek.....			93	60'		
Ramsey Creek.....			94-96	55'		
New Bridge.....	708.5	9.3	97-103	55'	477.0	
Mitchell Creek.....			104-109	50'		.00033
Loudon Bridge.....	757.5	4.6	110-112	50'	493.0	.00028
Cowden Bridge.....	782.0	148.1			500.0	

PROPOSED LEVEE GRADES—KASKASKIA RIVER.

Station.	Locality.	Grade elevation.	Grade slope.
132.5.....	New Athens.....	396.0	
213.0.....	Big Mud Creek.....	400.0	.00013
268.5.....	Elkhorn Creek.....	409.0	.00016
306.5.....	Sugar Creek.....	415.9	.000185
318.0.....	Shoal Creek.....	418.0	.000185
375.5.....	Crooked Creek.....	428.5	.000185
444.0.....	Carlyle.....	437.0	.000125
496.5.....	East Fork Diversion.....	447.0	.00019
542.0.....	Hurricane Creek.....	458.0	.00024
583.5.....	Shobonier Bridge.....	469.0	.000268
640.0.....	Vandalia.....	483.0	.00025
682.5.....	Ramsey Creek.....	497.0	.000316
711.5.....	Big Creek.....	505.4	.00030
735.0.....	Beck Creek.....	512.6	.00030
747.5.....	Hog Creek Diversion.....	515.3	.00022

PROPOSED SHOAL CREEK GRADES.

Locality.	Station.	Cut-off number.	Bottom width.	Channel grade elevation	Bottom grade slope.	Miles.	
						Proposed route.	Present channel.
Junction Shoal Creek and Kaskaskia.....	0.000	<i>Inclusive.</i>	<i>Feet.</i>	384.0	.00046	12.4	19.9
Breese.....	65.000	1-22	55	414.0			
East Fork.....	173.800	23-40	55				
Highway Bridge N. W. ½ Sec. 23 T. 5 N. R. 4 W. 3d P. M.	198.000	41-43	40	464.0	.00038	25.1	33.9
						37.5	53.8

The length of the old channel used, the number and length of the cut-offs, the depth of the channels, the depth of overflow above bank in the flood-way as designed, the top width of the old channels, the area of cross-section of the old channel and of the cut-offs, the bottom widths of the cut-offs, flood slopes and watershed of the Kaskaskia river from New Athens to Cowden Bridge are given in the following table:

KASKASKIA RIVER CHANNEL DESIGN.

Old channel proposed to be used—Length—Feet.	Proposed Cut-Offs.		Depth from proposed H. W. to bank stage—Feet.	Depth at bank stage—Feet.	Top width of old channel—Feet.	Area at bank stage—Square feet.	Bottom width of cut-offs—Feet.	Excavation—Cubic yards.	Proposed flood slope.	Bottom grade slope.	Drainage area.
	Number.	Length—Feet.									
98,650	1	900					100	70,300		.00005	5,525
300	2	2,150					100	97,400			5,525
18,050	3	850					100	54,100			5,540
25,100	4	550					100	27,400			5,200
2,950	5	600					100	46,900			5,200
19,200	6	1,400					100	102,600			5,200
1,100	7	650					100	41,400			5,200
2,850	8	2,800	13.1			2,400	100	178,200	.00005		5,200
17,700	9	500	13.3	20.1	300	4,450	100	47,200	.00013		4,700
250	10	450	13.4	20.3			100	47,200			4,700
8,000	11	700	13.7	20.4			100	69,600	.00013		4,700
8,300	12	950	13.8	20.7			100	99,500	.00016		4,575
1,750	13	750	14.5	20.8			100	111,700		.00007	4,575
23,950	14	1,300	14.2	21.0	200	2,540	100	122,400			4,575
8,200	15	1,300	14.2	21.8		3,600	100	122,400			4,575
4,200	16	1,500	14.2	22.0			100	141,300			4,575
2,200	17	800	13.9	22.1			100	79,600			4,575
2,500			13.6	22.2			100				4,575

KASKASKIA RIVER IMPROVEMENT.

Kaskaskia River Channel Design—Continued.

Old channel proposed to be used—Length—Feet.	Proposed Cut-Offs.		Depth from proposed H.W. to bank stage—Feet.	Depth at bank stage—Feet.	Top width of channel—Feet.	Area at bank stage—Square feet.	Bottom width cut-off—Feet.	Excavation—Cubic yards.	Proposed flood slope.	Bottom grade slope.	Drainage area.
	Number.	Length—Feet									
9,900	18	1,900	13.5	22.5	210	2,760 3,550	100	169,100	.00016	.00016	4,575
700	19	2,100	12.7	22.8			100	196,500	.000185	.00025	4,415
500	20	700	12.7	22.8			100	58,750			4,415
10,100	21	1,000	12.0	23.0	200	2,830 3,450	100	99,400			4,415
1,150	22	1,300	11.7	22.7			100	102,700			4,415
200	23	250	11.7	22.6			100	13,800			4,415
6,100	24	500	11.6	22.4			100	32,800			4,415
17,900	25	900	11.3	21.7			100	94,100			4,375
1,700	26	800	10.9	21.3			100	79,600			3,270
750	27	450	10.8	21.2			100	44,750			3,270
2,400	28	600	10.7	21.1			100	53,500			3,270
2,050	29	200	10.5	21.0			100	19,900			3,170
2,300	30	450	10.5	20.8			100	37,900			3,170
5,150	31	850	10.4	20.6			100	84,500			3,170
11,100	32	700	10.4	20.2			100	62,400			3,170
26,700	33	700	9.8	19.2	240	2,430 3,100	100	62,400	.000185	.00025	3,170
5,750	34	1,500	10.3	18.3			100	133,600	.000125	.00017	2,680
	35	550					100	40,700			2,680

KASKASKIA RIVER IMPROVEMENT.

[illegible]

KASKASKIA RIVER IMPROVEMENT.

Kaskaskia River Channel Design—Continued.

Old channel proposed to be used—Length—Feet.	Proposed Cut-Offs.		Depth from proposed H. W. to bank stage—Feet.	Depth at bank stage—Feet.	Top width of old channel—Feet.	Area at bank stage—Square feet.	Bottom width of cut-offs—Feet.	Excavation—Cubic yards.	Proposed flood slope.	Bottom grade slope.	Drainage area.
	Number.	Length—Feet.									
4,800	60	900	8.9	20.1			95	85,800			2,335
2,450	61	850	8.8	20.2			95	81,000			2,335
1,300	62	400	8.8	20.2			95	36,100	.00024		2,335
750	63	1,350	8.8	20.2			85	105,000	.000268		2,135
2,800	64	500	8.8	20.2			85	43,600			2,135
7,900	65	2,100	8.7	20.3	135	2,130 2,450	85	183,300			2,135
700	66	300	8.7	20.3			85	26,200			2,135
800	67	700	8.7	20.3			85	57,700			2,135
700	68	800	8.6	20.4			85	66,000			2,135
2,300	69	1,000	8.6	20.4			85	77,800			2,135
1,100	70	300	8.6	20.4			85	24,700			2,135
8,550	71	1,200	8.6	20.4			85	93,300			2,135
400	72	1,350	8.5	20.5			85	105,000			2,135
6,300	73	1,200	8.5	20.5		2,160 2,250	85	93,300	.000268		2,135
2,600	74	200	8.5	20.5	160		85	15,000	.00025		1,965
650	75	350	8.5	20.4			85	24,000			1,965
2,850	76	350	8.5	20.3			85	24,000			1,965
	77	700	8.5	20.3			85	51,200			1,965

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4,100	78	400	8.5	20.2	157	2,000 2,225	85	31,100	.00025 .000316	1,905
17,350	79	500	8.5	20.0			85	29,400		1,905
9,650	80	350	8.5	19.6			85	22,500		1,905
3,750	81	700	8.6	19.4			85	54,500		1,905
2,200	82	500	8.7	19.3			85	41,200		1,905
6,300	83	1,100	8.9	19.1			85	80,500	.00025 .000316	1,905
1,900	84	450	9.0	19.0			65	28,300		1,905
12,000	85	1,050	8.8	19.0			65	58,100		1,905
7,000	86	2,700	8.0	19.0			65	152,000		1,905
3,200	87	800	7.8	19.0	185	1,595 2,500	65	44,300		1,905
200	88	300	7.9	19.0			65	16,600		1,905
3,300	89	800	8.0	18.8			65	44,200		1,905
1,900	90	350	8.0	18.6			65	16,800		1,905
2,450	91	700	8.2	18.4			65	38,700		1,905
1,900	92	600	8.3	18.2			65	31,000		1,905
1,300	93	650	8.3	18.0			60	33,800	.000316	1,905
10,350	94	400	8.4	17.5			55	18,100	.00030	1,730
2,600	95	2,000	8.6	17.0			55	53,800		1,730
1,300	96	700	8.8	16.7			55	31,700	.00036	1,730
17,100	97	900	8.9	16.0	230	1,100 2,850	55	21,700	.00033	1,645
5,350	98	950	9.0	15.2			55	31,100		1,645
600	99	550	9.0	14.9			55	19,700		1,645
600	100	500	9.0	14.8			55	21,000		1,645
700	101	700	9.0	14.8			55	29,400		1,645
2,500			9.0	14.6			55			

Kaskaskia River Channel Design—Concluded.

Old channel proposed to be used—Length—Feet.	Proposed Cut-Offs.		Depth from proposed H. W. to bank stage—Feet.	Depth at bank stage—Feet.	Top width of old channel—Feet.	Area at bank stage—Square feet.	Bottom width of cut-offs—Feet.	Excavation—Cubic yards.	Proposed flood slope.	Bottom grade slope.	Drainage area.
	Number.	Length—Feet									
800	102	900	9.0	14.5			55	21,700			1,645
6,700	103	400	9.0	14.2			55	15,600	.00030		1,645
2,400	104	500	9.0	13.8			50	19,600	.00022		1,415
1,250	105	200	9.0	13.7			50	8,400			1,415
1,650	106	550	9.0	13.6			50	21,500			1,415
600	107	350	9.0	13.5			50	12,700	.00022		1,415
3,400	108	900		13.4			50	37,900			1,325
6,600	109	300		13.4			50	11,700	.00033		1,325
15,600	110	800		12.8			50	36,300	.00028		1,325
3,600	111	1,000		12.6			50	39,100			1,325
*1,000	112	1,200		12.5	120	785 1,475	50	46,900			1,325

* To Cowden bridge.

EFFECT OF REDUCING STORAGE.

There are 146,000 acres of overflowed land in the Kaskaskia bottoms between Cowden Bridge and New Athens, which now acts as a flood basin or storage reservoir for the water that comes from the adjacent hill streams into the valley. This flood basin fills from bank-full to extreme high water level in from four to six days and requires about an equal length of time after maximum stage has been reached until the river is again within its banks, depending upon the intensity and duration of the rain period. Of this area 140,000 acres are to be reclaimed and will not be available for the storage of the flood waters. These flood waters must, therefore, be carried through the valley in substantially the time in which they have heretofore filled the storage. The overflowed portion of the valley besides furnishing storage has also been a flood-way and the amount of measured discharge is about three times the carrying capacity of the channel of the stream. The flood-ways have been provided for by leaving space between the levees and with the levees of sufficient height to provide for carrying the amount of run-off, or flood flow, as determined from the studies hereinbefore described. The widths of flood-ways, beginning at the upper end, are as follows:

	Feet.
From Hog Creek Diversion to Ramsey Creek	1,000
Ramsey Creek to Vandalia	1,025
Vandalia to Shobonier Bridge	1,050
Shobonier Bridge to Hurricane Creek	1,075
Hurricane Creek to East Fork Diversion	1,100
East Fork Diversion to Crooked Creek	1,200
Crooked Creek to Shoal Creek	1,250
Shoal Creek to Sugar Creek	1,350
Sugar Creek to Elkhorn Creek	1,375
Elkhorn Creek to Big Mud Creek	1,400
Big Mud Creek to Silver Creek	1,500
Silver Creek to New Athens	1,700

The ruling points for the heights of levees have been taken at Vandalia, Carlyle and New Athens at about three feet above the maximum flood heights as they have occurred in the past. Bridge openings for the public highways and railways must be made to correspond to the flood-ways as provided. The flood-way is very much restricted at Vandalia and Carlyle by the construction of levees, bridges, road and railroad embankments and natural barriers. The natural flood-slope sags several feet below a uniform gradient between these points. When the protection levees are constructed the flood plane between the levees will approximate very much more nearly to a uniform gradient.

An outline profile, showing the bottom of the stream, the river bank, the old flood slope grade line, and the grade line of the tops of the proposed levees, has been prepared to show the relation of the old flood plane to the proposed flood plane. Upon this profile sheet is also shown diagrammatically the location and changes in width of the proposed flood-way.

The location for construction of the cut-offs, the main levees along the Kaskaskia river, and the channels and levees for the tributary streams and diversion bluff ditches will be made from the detailed surveys and

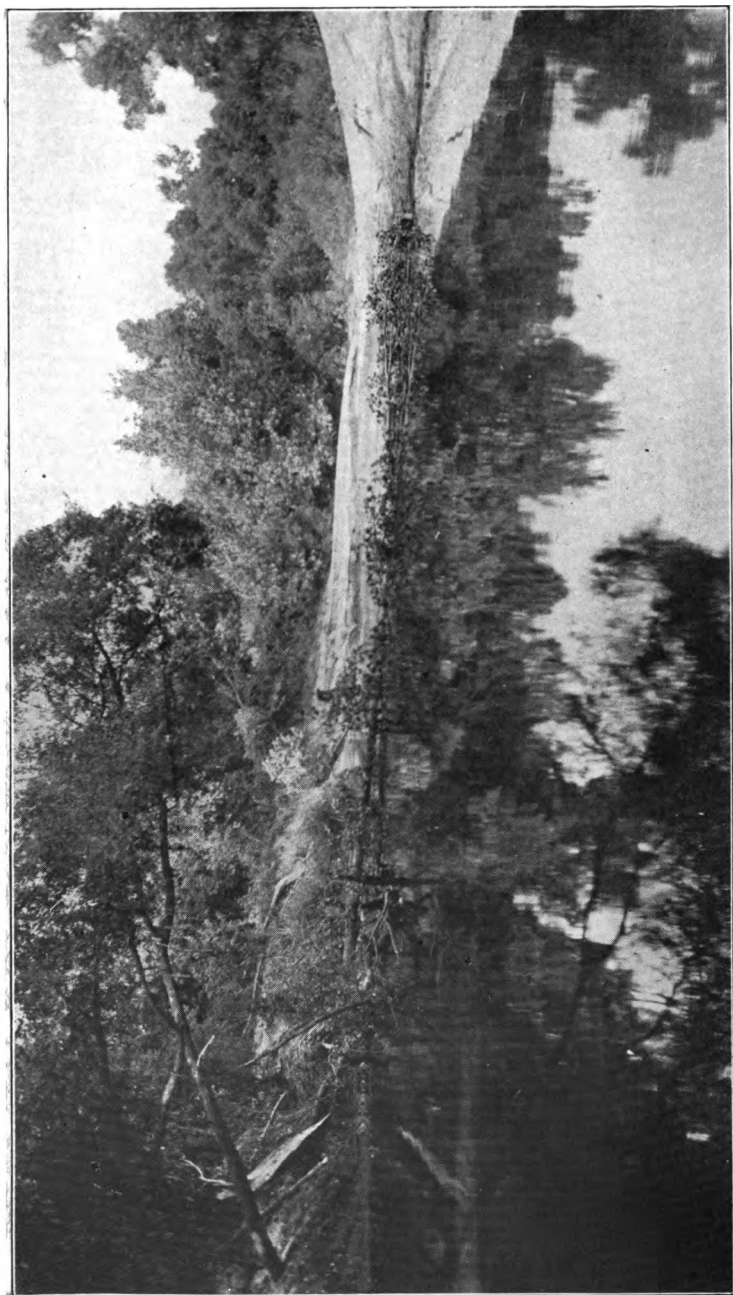
studies for location purposes. Modifications of the locations, dimensions of channels, flood-way and levees may be made from these detailed surveys in accordance with the requirements for such channels and flood-ways, as set out in this discussion under "Rainfall and Run-Off."

TRIBUTARY STREAMS.

The tributary streams entering the valley overflow their banks, and to some extent the lands which are subject to overflow by the high waters of the Kaskaskia river. It is necessary, therefore, to construct channels and levees for controlling the flood waters of the tributaries until they reach the channel of the main stream. Locations for these channels and levees are shown upon the plans from the point where the tributary stream enters into the overflowed area of the Kaskaskia valley proper. They are generally taken by the most direct route to the main stream; some cases, however, the tributary streams are carried along the foot of the bluffs before entering the main streams, or are combined with the gravity outlets for the drainage of the low lands.

The plans and estimates for Shoal creek contemplates only the straightening of the main channel by construction of cut-offs of the large bends, as shown upon the plans. The overflowed area of the Shoal creek valley is narrow and the duration of the floods short, as compared with the duration of the floods in the Kaskaskia valley. We have not undertaken to determine or make any estimates for the leveeing of any portions of the Shoal creek valley. This can be handled by the individual land owners if found desirable after the straightening of the channel of the stream.

The lengths by stationing, the bottom widths, the drainage area and grade elevations, and other data of the tributary streams are shown in the following table.



Sand bar and driftwood in bend.

TRIBUTARY STREAMS DESIGN.

Diversion Channel.	Station.	Grade elevation.	Bottom width—Feet.	Bottom grade slope.	Drainage area—Square miles.	Location of station "O"	Levee.	
							Grade elevation.	Grade slope.
Big Mud Creek.....	0.000	375.0	25	.00062	125	Sta. 213 Kaskaskia	400.0	.0002
Big Mud Creek.....	13.000	383.0					402.6	
Silver Creek.....	0.000	371.0	40	.0002	500	Sta. 184.5 Kaskaskia	396.0	.0002
Silver Creek.....	6.000		40				397.2	
Silver Creek.....	8.000	372.6						
Sugar Creek.....	0.000	386.5	30	.0005	175	Sta. 306.5 Kaskaskia	415.9	.0004
Sugar Creek.....	7.000	390.0	30	.00032			418.7	.0001
Sugar Creek.....	18.000	393.5					419.8	
Sugar Creek.....		397.0						
Elkhorn Creek.....	0.000	381.0	20	.0004	100	Sta. 288.5 Kaskaskia	409.0	.0001
Elkhorn Creek.....	15.000	387.0					410.5	
Shoal Creek.....	(See separate sheet)							
Plum Creek.....	0.000	391.0	25	.0008	40	Sta. 296.5 Kaskaskia	414.0	.000256
Plum Creek.....								
Plum Creek.....	5.000	395.0	25	.0032				
Plum Creek.....	7.500	403.0	25	.00033				
Plum Creek.....	19.500	407.0		.00033				
Plum Creek.....	23.000						419.0	

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Tributary Streams Design—Concluded.

Diversion Channel.	Station.	Grade elevation.	Bottom width—Feet.	Bottom grade slope.	Drainage area—Square miles.	Location of station "O"	Levee.	
							Grade elevation.	Grade slope.
Crooked Creek.....	0.000	401.4	80	.00037	490	Sta. 375.5 Kaskaskia	428.5	.0001
Crooked Creek.....	15.000	407.0	70	.00037	370		432.4	
Crooked Creek.....	34.000	414.0	50	.00016	100		447.0	.00071
Crooked Creek.....	38.500	414.7			290	Sta. 496.5 Kaskaskia	457.0	
East Fork.....	0.000	425.0	40	.00008		Sta. 14.0 East Fork	457.0	.0001
East Fork.....	14.000	439.4			100		458.3	
East Fork.....	18.000	436.2	35	.00025		Sta. 542.0 Kaskaskia	458.0	.0002
Louse Creek.....	0.000	439.0	40	.00053	200	Sta. 24.3 Dist. 22 Gravity Outlet	462.0	.001
Louse Creek.....	11.000	434.0				Sta. 644.0 Kaskaskia	464.0	.00045
Louse Creek.....	13.000	443.8			60		484.3	
Hurricane Creek.....	0.000	451.0	8	.0001		Sta. 661.0 Kaskaskia	491.5	.00025
Buck Creek.....	18.500	443.8					496.0	
Buck Creek.....	20.000	451.0						
Buck Creek.....	0.000	469.0	25	.00056				
Bear Creek.....	0.000	478.0	8	.00125				
Linn Creek.....	16.000	473.0						
Linn Creek.....	0.000							

Linn Creek.....	9.000	484.2				488.3		.0002
Ash Creek.....	0.000	482.0				500.0		
Ash Creek.....	8.500	484.5	20	.0003	45	501.7	Sta. 6.0 Ramsey Creek	
Ramsey Creek.....	0.000	478.0	30	.00067	160	497.0	Sta. 682.5 Kaskaskia	.0005
Ramsey Creek.....	6.000	482.0	25	.0016	115	500.0		.00036
Ramsey Creek.....	11.500	490.8				502.0		
Hog Creek.....	0.000	495.0	20	.0005	90	515.3	Sta. 747.5 Kaskaskia	.0003
Hog Creek.....	4.000	497.0				516.5		
Suck Creek.....	0.000	475.0	8	.002	20	499.3	Sta. 691.5 Kaskaskia	.0002
Suck Creek.....	5.000	485.0				500.3		
Big Creek.....	0.000	483.4	30	.0009	85	505.4	Sta. 711.5 Kaskaskia	.0009
Big Creek.....	8.500	491.0				513.0		.0001
Big Creek.....	18.500	495.0		.0904		514.0		

BLUFF DIVERSION DITCHES.

In addition to the larger tributary streams there are a great many small streams and gullies along the bluffs that discharge their water upon and overflow the bottom lands. From such small streams and gullies there is seldom any channel leading to the river, and in some locations large areas of the land lying between the foot of the bluffs and the river are maintained in a swampy condition throughout a large portion of the year by the discharge of these smaller streams, and by the under-drainage from the higher lands, frequently in the form of springs. To protect the lands from swamping and flooding by these bluff streams what are known as bluff, or diversion ditches, are designed for a number of the drainage districts. These ditches are frequently, as above stated, combined with the hill streams, which have definite channels through the bottoms to the river channel.

SEDIMENTATION AREAS.

The smaller streams from the immediate hills usually carry a large amount of sediment and drift, which is deposited at the foot of the grade and is continually filling up the lands where these streams enter the flat valley. It is for this reason that these smaller streams have not established permanent channels for themselves. If ditches are constructed connecting these small hill streams directly with the main drainage ditches, or stream channels, the same process of filling by sedimentation will continue and such ditches will soon be entirely obliterated where the filling occurs. To overcome this filling of the ditches that are to be constructed, and to control the extent of flooding where the streams leave the steep grades and enter the flat valley, it will be necessary to provide *sedimentation areas* surrounded by levees, arranged with a proper inlet at the upper or higher end of the sedimentation area and a protected outlet at the lower end. By this method the sediment and drift can be controlled within a limited area and when the flood water, freed from its excess sediment and drift, is again gathered into the ditches there will be no further or unusual trouble in the maintenance of the ditches. When such sedimentation area shall have been filled to such a height that it may not be further adaptable to the continued use as a sedimentation area, it will have been built up with fertile soil to such a height that it will have good natural drainage outlet to the adjacent ditches or lower land, and a new tract adjacent thereto may be taken for the sedimentation area.

In this way land which has once done service as a sedimentation area will subsequently become available for farming, and experience shows that such areas are most productive. The sedimentation area while in use as such will furnish only limited opportunity for farming or grazing so that the drainage district should acquire, by lease or condemnation, the right to use the land for such sedimentation areas. An annual rental for this purpose is best, because when the land shall no longer be most suitable for a sedimentation area, it will then revert to the full use of the owner and an adjacent tract can be taken at an annual rental, so long as may be needed, without disturbing the title.

DRAINAGE UNITS.

The construction of the bluff diversion ditches and the channels for the tributary streams through the low lands divides the overflowed area so that, in the drainage of the lands to make them suitable for tillage, they are thus naturally divided into separate drainage areas or drainage units. The proximity of the river channel to the bluffs or higher lands at frequent intervals also contributes to the separation of overflowed lands into drainage units. Between New Athens and Cowden Bridge we have planned twenty-eight drainage units, numbered from 1 to 28, inclusive. Those bearing the even numbers are located on the west bank of the Kaskaskia river, and those bearing the odd numbers are located on the east bank of the Kaskaskia. The areas of these drainage units vary from 600 acres to nearly 15,000 acres. Between these areas there are a number of tracts of land for which no provision for protection from overflow has been designed on account of the small area or narrow width. These unprotected areas aggregate about 6,000 acres.

DESCRIPTION OF THE DRAINAGE UNITS.

A detailed description of the drainage units, including the character, extent and approximate estimate of cost of protection from overflow for each is as follows:

Drainage Unit No. 1—Containing 1,765 acres, averages less than one mile wide on the east bank of the Kaskaskia river and extends from New Athens, a distance of about 5 miles, to Big Mud creek.

The average height of the proposed river levee is 16'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee	639,900	Cu. Yds.
Big Mud Creek Levee (left bank)....	70,100	" "

Total 710,000 " " @ 12½c \$88,750.00
 $\$88,750.00 \div 1,765 \text{ acres} = \$50.28$, average cost per acre.

Drainage Unit No. 2—Containing 4,390 acres, averages about 1½ mile wide on the west bank of the Kaskaskia river and extends from Silver creek, immediately above New Athens, a distance of about 6 miles, to Fayetteville.

Silver creek, which forms the lower boundary of the drainage unit, is to be straightened and leveed and a bluff ditch and levee constructed, beginning about 1½ miles west of Fayetteville and extending southwesterly along the foot of the bluffs to Silver creek.

The average height of the proposed river levee is 17.5'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee	917,000	Cu. Yds.
Silver Creek Levee	92,900	" "
Bluff Ditch and Levee	190,000	" "

Total 1,199,900 " " @ 12½c \$149,987.50
 $\$149,987.50 \div 4,390 \text{ acres} = \$34.16$, average cost per acre.

Drainage Unit No. 3—Containing 7,653 acres, averages about 2 miles wide on the east bank of the Kaskaskia river and extends from Big Mud creek about 2 miles south of Fayetteville, a distance of about 8 miles, to a point about one-quarter mile east of the St. Clair-Washington county line.

A bluff ditch and levee will begin at the foot of the bluffs at the St. Clair-Washington county line and extend southwesterly to the lower end of the drainage unit and connect with the Big Mud creek channel and levee. This bluff ditch as proposed cuts off a portion of the overflowed land, and double levees are required for the protection of this portion. The drainage of this land can be accomplished by carrying a pipe, or closed drain, under the channel into the outlet drainage ditches which may be constructed.

The average height of the proposed river levee is 18.1'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee	1,406,000	Cu. Yds.
Big Mud Creek Levee	96,200	" "
Bluff Ditch and Levee	384,200	" "

Total 1,886,400 " " @ 12½c \$235,800.00
 $\$235,800.00 \div 7,653 \text{ acres} = \$30.81$, average cost per acre.

Drainage Unit No. 4—Containing 10,945 acres, averaging about 3 miles wide on the west bank of the Kaskaskia river and extends from the point where the Kaskaskia river channel approaches the bluff 2 miles west of the St. Clair-Clinton county line, a distance of about 8 miles, to Sugar creek channel. A bluff ditch and levee begins near the north end of this drainage unit and follows substantially along the foot of the bluff to an outlet into the Kaskaskia river at the lower end of the district.

New Memphis station is located in about the center of this drainage unit.

The average height of the proposed river levee is 18'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	1,437,800	Cu. Yds.
Sugar Creek Levee	208,200	" "
Bluff Ditch and Levee	325,400	" "

Total 1,971,400 " " @ 12½c \$246,825.00
 $\$246,825.00 \div 10,945 \text{ acres} = \$22.55$, average cost per acre.

Drainage Unit No. 5—Containing 4,515 acres, averages about 2 miles wide on the east bank of the Kaskaskia river and extends from Elkhorn creek near the St. Clair-Washington county line, a distance of about 5 miles, to the Louisville & Nashville Railroad. A bluff ditch and levee begins near the upper end of this drainage unit and extends along the foot of the bluff to the proposed diversion channel of Elkhorn creek about midway of the drainage unit. The Elkhorn channel and levee extends thence along the foot of the bluff to the Kaskaskia river at the lower end of the district.

Windom postoffice at Vennedy station, on the Louisville & Nashville Railroad, is located at the upper end of this drainage unit at the foot of the bluff.

The average height of the proposed river levee is 19.1'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee	741,800	Cu. Yds.	
Elkhorn Creek Levee	181,000	"	"
Bluff Ditch and Levee	105,400	"	"
Total	1,028,200	"	" @ 12½c \$128,525.00

\$128,525.00 ÷ 4,515 acres = \$28.47, average cost per acre.

Drainage Unit No. 6—Containing 4,550 acres, averages about 1½ miles wide on the east bank of the Kaskaskia river and extends from the north bank of Sugar creek channel, a distance of about 6 miles, to within about 2 miles of Germantown on the west bank of Shoal creek. A bluff ditch and levee begins at the upper end of this drainage unit and follows the foot of the bluff to Sugar creek channel.

The average height of the proposed river levee is 16.5'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee	275,000	Cu. Yds.	
Shoal Creek Levee	197,700	"	"
Sugar Creek Levee	112,100	"	"
Bluff Ditch and Levee	311,800	"	"
Total	896,600	"	" @ 12½c \$112,075.00

\$112,075.00 ÷ 4,550 acres = \$24.63, average cost per acre.

Drainage Unit No. 7—Containing 5,835 acres, averages about 1½ miles wide on the east bank of the Kaskaskia river and extends from the Louisville & Nashville Railroad, a distance of about 6 miles, to a point where the Kaskaskia river channel leaves the bluff lands. The bluff ditch and levee begins at the upper end of the drainage unit and extends along the foot of the bluffs, a distance of about 4 miles, to Plum creek from which point it enters Plum creek diversion channel, which follows the foot of the bluffs; thence to the Louisville & Nashville Railroad; thence along the railroad to the Kaskaskia river channel.

The average height of the proposed river levee is 16.5'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	1,056,000	Cu. Yds.	
Plum Creek Levee.....	59,800	"	"
Bluff Ditch and Levee.....	100,700	"	"
Total	1,216,500	"	" @ 12½c \$152,062.50

\$152,062.50 ÷ 5,835 acres = \$26.06, average cost per acre.

Drainage Unit No. 8—Containing 9,920 acres, averages about 3 miles wide on the west bank of the Kaskaskia river and extends from Shoal creek, a distance of about 6 miles, to the lower end of the Santa Fé levee. A bluff ditch and levee begins about 2 miles east of the west boundary of the drainage unit and extends in an easterly direction along the foot of the bluff to the northeast corner of the district where it joins

the bluff ditch from Drainage Unit No. 10; thence south on the east boundary of Drainage Unit No. 8 to the gravity outlet channel of Drainage Unit No. 10 near the Kaskaskia river.

A gravity outlet for Drainage Unit No. 10 follows along the Kaskaskia river levee on the south side of Drainage Unit No. 8 to within about 1 mile of Shoal creek. Drainage Unit No. 8 is protected from overflow by bluff ditch and levee on the north and east; by levee along the gravity outlet and the Kaskaskia river levee on the south; and a levee along Shoal creek on the west.

The Hanover drainage ditch begins near the northeast corner of this drainage unit and extends in a southwesterly direction to its present outlet into Shoal creek.

The average height of the proposed river levee is 15.2'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	714,800	Cu. Yds.
Shoal Creek Levee.....	265,000	" "
Bluff Ditch and Levee.....	145,000	" "
Ditch and Levee for same between Drainage Units No. 8 and No. 10.	146,900	" "

Total 1,271,700 " " @ 12½c \$158,962.50
 $\$158,962.50 \div 9,920 \text{ acres} = \$16.02$, average cost per acre.

Drainage Unit No. 9—Containing 4,480 acres, averages about 11¼ miles wide on the east bank of the Kaskaskia river and extends from the Kaskaskia river, a distance of about 7 miles, up the valley of Crooked creek. This drainage unit differs from the others in that it follows up the valley of Crooked creek and has a frontage on the Kaskaskia river channel of only about 2 miles.

Crooked creek channel is to be relocated along the south and east bluff line, with a levee on the north and west side of the channel to protect the low lands from overflow.

The average height of the proposed river levee is 14.6'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	254,200	Cu. Yds.
Crooked, Lost and Coon Creek Levee	93,400	" "

Total 347,600 " " @ 12½c \$43,450.00
 $\$43,450.00 \div 4,480 \text{ acres} = \$9.70$, average cost per acre.

Drainage Unit No. 10—Containing 8,870 acres, averages about 3 miles wide on the west bank of the Kaskaskia river and extends from Drainage Unit No. 8, a distance of about 6 miles, to a point where the Kaskaskia river leaves the bluff line about 4 miles south of Carlyle. A bluff ditch begins near the northeast corner of the drainage unit and follows the foot of the bluff in a southwesterly direction to the junction with the bluff ditch of Drainage Unit No. 8; thence south along the west boundary of Drainage Unit No. 10 to the gravity outlet of Drainage Unit No. 10.

Drainage Unit No. 10 is protected from overflow by levees along the Kaskaskia river and the bluff ditch levees. At the southwest corner of this drainage unit the levee along the west side connects with the Kas-

kaskia river levee. Through this bluff ditch levee at the southeast corner will be constructed a sluiceway with gates into the gravity outlet channel, which follows the Kaskaskia river channel along the south boundary of Drainage Unit No. 8 to the outlet into the Kaskaskia river near Shoal creek. These gates will be operated so as to prevent the flooding of Drainage Unit No. 10 by the storm waters flowing through the bluff ditch into the gravity channel, and when the storm waters have passed the gates be opened to permit of the gravity drainage of Unit No. 10 through the gravity outlet.

Within Drainage Unit No. 10 is the Santa Fé levee and ditches, as shown upon the plans.

The average height of the proposed river levee is 14.2'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	900,300 Cu. Yds.
Bluff Ditch and Levee.....	103,000 " "
Ditch and Levee for same between	
Drainage Units No. 8 and No. 10.	146,900 " "
Gravity Ditch and Levee.....	366,900 " "

Total 1,517,100 " " @ 12½c \$189,637.50
 $\$189,637.50 \div 8,870 \text{ acres} = \$21.38$, average cost per acre.

Drainage Unit No. 11—Containing 1,990 acres, averages about 1 mile wide on the east bank of the Kaskaskia river and extends from a point about 1 mile south of the Southern Railroad, a distance of about 4½ miles to where the Kaskaskia river leaves the bluffs on the east side of the bottoms about 2½ miles south of Carlyle.

The average height of the proposed river levee is 13.7'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	416,600 Cu. Yds. @ 12½c \$52,075.00
$\$52,075.00 \div 1,990 \text{ acres} = \$26.17$, average cost per acre.	

Drainage Unit No. 12—Containing 635 acres, averages about three-quarter mile wide on the west bank of the Kaskaskia river and extends from the point where the Kaskaskia river strikes the bluffs on the west side of the bottom lands about 2½ miles south of Carlyle, a distance of about 1¼ miles to the point where the river leaves the bluffs on the west side of the bottom lands.

The average height of the proposed river levee is 15.6'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	251,000 Cu. Yds. @ 12½c \$31,375.00
$\$31,375.00 \div 635 \text{ acres} = \$49.41$, average cost per acre.	

Drainage Unit No. 13—Containing 2,170 acres, averages about 1 mile wide on the east bank of the Kaskaskia river and extends a distance of 3½ miles from the point where the river strikes the bluffs on the east side of the bottom lands, about 2½ miles south of Carlyle, to the Chicago, Burlington & Quincy Railroad through Carlyle.

The average height of the levee is 14.6'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee..... 243,700 Cu. Yds. @ 12½c \$30,462.50
 $\$30,462.50 \div 2,170 \text{ acres} = \$14.04$, average cost per acre.

Drainage Unit No. 14—Containing 885 acres, averages about three-quarter mile wide on the west bank of the Kaskaskia river and lies immediately south of the city of Carlyle.

The average height of the proposed river levee is 15.8'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee..... 183,100 Cu. Yds. @ 12½c \$22,887.50
 $\$22,887.50 \div 885 \text{ acres} = \$25.86$, average cost per acre.

Drainage Unit No. 15—Containing 9,745 acres, averages about 2 miles wide on the east bank of the Kaskaskia river and extends a distance of about 10 miles from a point one-half mile above the public highway bridge at Carlyle to the proposed diversion channel of the East Fork creek, which forms a boundary between Drainage Units No. 15 and No. 17. The northerly end of this drainage unit is about three-quarter mile north of the Chicago, Burlington & Quincy Railroad. A bluff ditch and levee begins at Brewster creek near the north end of this drainage unit and extends southwesterly along the foot of the bluffs to the Kaskaskia river at the lower end of the drainage unit.

The gravity outlet for Drainage Unit No. 17 extends along the Kaskaskia river levee to an outlet into the Kaskaskia river at the lower end of Drainage Unit No. 15.

The average height of the proposed river levee is 15.9'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	915,900 Cu. Yds.
East Fork Creek Levee.....	1,300 " "
Bluff Ditch and Levee.....	438,500 " "

Total	1,355,700 " "	@ 12½c	\$169,462.50
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$\$169,462.50 \div 9,745 \text{ acres} = \$17.39$, average cost per acre.

Drainage Unit No. 16—Containing 2,800 acres, averages about 1 mile wide on the west bank of the Kaskaskia river and extends a distance of about 4 miles, from a point where the Kaskaskia river strikes the bluffs on the west side of the bottom lands, north of the city of Keyesport. For this drainage unit there is planned a bluff ditch and levee beginning near the north end of the drainage unit, about one-half mile south of the city of Keyesport; thence southerly along the foot of the bluffs to where it enters the Kaskaskia river at the south end of this drainage unit.

The average height of the proposed river levee is 13.7'.

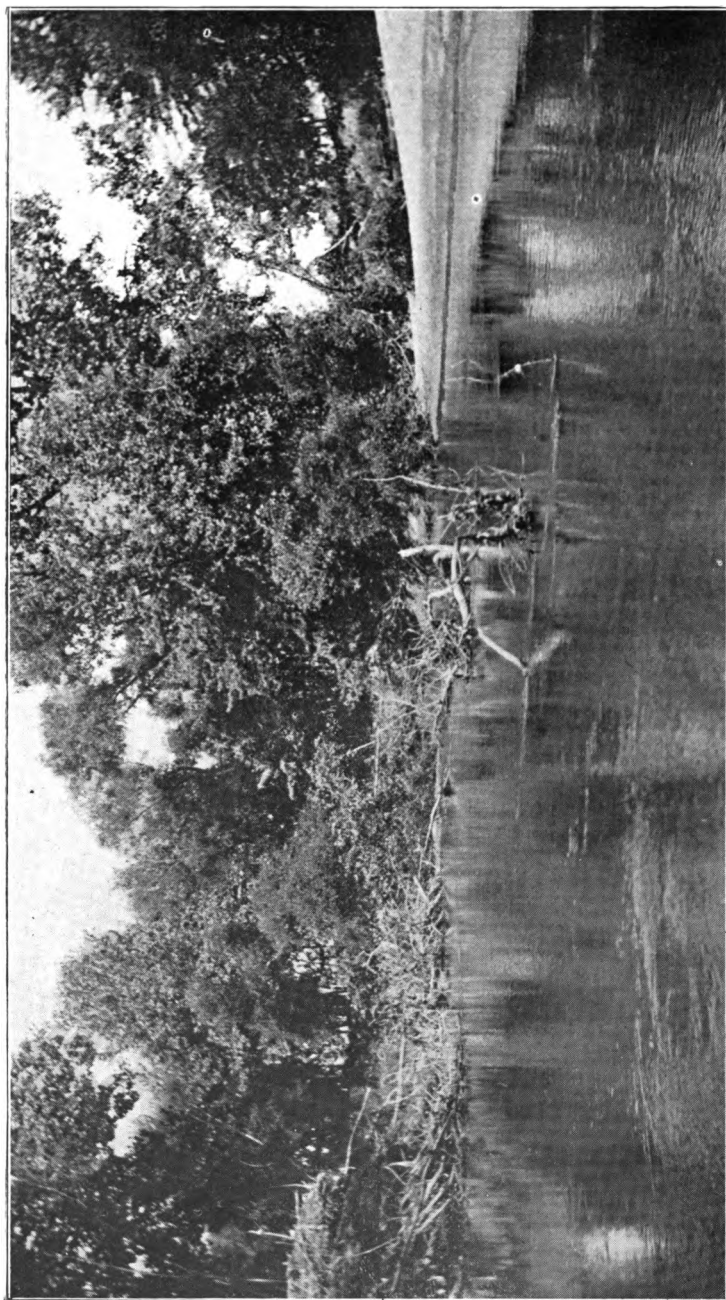
The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	462,900 Cu. Yds.
Bluff Ditch and Levee.....	157,300 " "

Total	620,200 " "	@ 12½c	\$77,525.00
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$\$77,525.00 \div 2,800 \text{ acres} = \$27.69$, average cost per acre.

Drainage Unit No. 17—Containing 8,595 acres, averages about 2 miles wide on the east bank of the Kaskaskia river and extends from a



Channel choked with driftwood.

point about 1 mile south of the Chicago, Burlington & Quincy Railroad, a distance of about 7 miles, northerly to where the Kaskaskia river leaves the bluff at Pope's bluff.

The city of Keyesport is situated directly east across the river from this drainage unit.

A diversion channel and levee is proposed for the diversion of the waters of Louse and East Fork creeks, beginning at the bluffs on the east of the bottoms at a point about one-half mile north of the Fayette-Clinton county line, and extending thence southerly along the foot of the bluffs; thence across the bottoms between Drainage Units No. 15 and No. 17 to an outlet into the Kaskaskia river. In this drainage unit there is now what is known as Soper lake drainage ditch and branches having an outlet into the present channel of the Kaskaskia river. This drainage ditch receives the waters from a number of smaller streams from the bluffs; and to furnish an outlet for these waters there is designed a gravity outlet ditch and levee. This gravity outlet ditch is to extend from the present outlet of Soper lake ditch about 1 mile north of the Fayette-Clinton county line; thence southerly to the south end of this drainage unit; thence by an inverted siphon under the proposed East Fork diversion channel and levees; thence with a ditch and levee southerly along the Kaskaskia river levee to a point near the south end of Drainage Unit No. 15, to its outlet into the Kaskaskia river.

The average height of the proposed river levee is 14'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	852,200	Cu. Yds.
East Fork Creek Levee.....	1,300	" "
Louse Creek Levee.....	29,500	" "
Soper Lake Gravity Ditch and Levee	376,500	" "

Total 1,459,500 " " @ 12½c \$182,437.50
 $\$182,437.50 \div 8,595 \text{ acres} = \$21.23$, average cost per acre.

Drainage Unit No. 18—Containing 2,565 acres, averages 1 mile wide on the west bank of the Kaskaskia river and extends from the city of Keyesport northerly, a distance of about 5 miles, to Hurricane creek channel. For this drainage unit there is planned a bluff ditch and levee beginning at the bluff on the west side of the bottoms at a point about 3 miles north of the city of Keyesport, and extends thence southerly along the foot of the bluffs to an outlet into the Kaskaskia river at the city of Keyesport.

The average height of the proposed river levee is 13.1'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	396,800	Cu. Yds.
Hurricane Creek Levee.....	13,200	" "
Bluff Ditch and Levee.....	131,100	" "

Total 541,100 " " @ 12½c \$67,637.50
 $\$67,637.50 \div 2,565 \text{ acres} = \$26.37$, average cost per acre.

Drainage Unit No. 19—Containing 6,085 acres, averages $1\frac{1}{2}$ miles wide on the east bank of the Kaskaskia river and extends from a point about one-half mile east of Pope's bluff northerly about 8 miles to a point about 1 mile west of Shobonier.

In this drainage unit the Wild Cat drainage ditch and branches receive the waters from several small hill streams; and to afford an outlet for these waters there is planned a gravity ditch and levee beginning near Pope's bluff and extending thence southerly along the Kaskaskia river levee, and along the westerly side of Drainage Unit No. 17 to an outlet into the Kaskaskia river at a point about one-quarter mile north of the Fayette-Clinton county line.

The average height of the proposed river levee is 14.2'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	916,900 Cu. Yds.
Gravity Ditch and Levee.....	315,200 " "

Total	1,232,100 " "	@ $12\frac{1}{2}$ c	\$154,012.50
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$\$154,012.50 \div 6,085 \text{ acres} = \$25.31$, average cost per acre.

Drainage Unit No. 20—Containing 4,620 acres, varies in width from one-half to 2 miles on the west bank of the Kaskaskia river and extends from Hurricane creek northerly, a distance of about 6 miles, to Buck creek. This drainage unit will be protected from overflow by the Kaskaskia river levee, by a levee along the proposed channel of Hurricane creek and by a levee along Muddy creek, extending from the Hurricane creek levee along the left bank of Muddy creek and ending at the bluff.

A gravity ditch and levee for Drainage Unit No. 22 will extend from Buck creek southerly along the Kaskaskia river levee to a point about midway of Drainage Unit No. 20 to its outlet into the Kaskaskia river.

The average height of the proposed river levee is 12.5'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	563,800 Cu. Yds.
Hurricane Creek Levee.....	16,100 " "

Total	579,900 " "	@ $12\frac{1}{2}$ c	\$72,587.50
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$\$72,587.50 \div 4,620 \text{ acres} = \$15.71$, average cost per acre.

Drainage Unit No. 21—Containing 14,720 acres, averages about $2\frac{1}{2}$ miles wide on the east bank of the Kaskaskia river and extends from a point about 1 mile west of Shobonier northerly a distance of about 13 miles to Linn creek.

About midway of this drainage unit, and on the opposite side of the river, is situated the city of Vandalia. This drainage unit now has a number of branch ditches which receive the waters from various small hill streams, aggregating a drainage area of about 170 square miles. To afford an outlet for these waters there is planned a gravity ditch and levee extending along the Kaskaskia river levee. The ditch for this system of ditch and levee extends from near the present outlet of the Vandalia ditch to a point about 2 miles north of Shobonier; thence southerly along the Kaskaskia river levee to a point about 1 mile west

of Shobonier; thence continuing with a ditch and levee along the Kaskaskia river levee, and along the north side of Drainage Unit No. 19, to its outlet into the Kaskaskia river opposite Buck creek.

The average height of the proposed river levee is 11.7'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	344,500	Cu. Yds.
Linn Creek Levee.....	37,100	" "
Vandalia Gravity Ditch and Levee.	502,900	" "

Total 884,500 " " @ 12½c \$110,562.50
 \$110,562.50 ÷ 14,720 acres = \$7.51, average cost per acre.

Drainage Unit No. 22—Containing 5,420 acres, averages about 2 miles wide on the west bank of the Kaskaskia river and extends from Buck creek, a distance of about 5 miles, northerly to a point where the Kaskaskia river leaves the bluff on the west side of the bottom lands, about 2 miles south of Vandalia.

This drainage unit now has a drainage ditch and laterals known as the Fish Lake drainage ditch, beginning near the north end of the drainage unit and extending southerly near the foot of the bluff to an outlet into the Kaskaskia river at the south end of the drainage unit near Buck creek. For this drainage unit there is planned a gravity ditch and levee extending from the south end of the drainage unit southerly along the Kaskaskia river levee, and along the easterly side of Drainage Unit No. 20, to an outlet into the Kaskaskia river at a point about 1½ miles north of Pope's Bluff.

Part of this drainage unit consists of what is known as Pecan Island, being an island formed by two arms of the Kaskaskia river. There is now under construction a levee surrounding this island, for the purpose of preventing its inundation during high water. It is not possible to say from the data at hand whether the part of this levee along the east side of the island can become a part of the levees herein proposed; it is probable, however, that the levee now being constructed is too near the bank of the river to fulfill the requirements for widths of flood-ways for the Kaskaskia river as the same are herein proposed and recommended.

The average height of the proposed river levee is 13'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	572,400	Cu. Yds.
Fish Lake Gravity Ditch and Levee	165,100	" "

Total 737,500 " " @ 12½c \$92,187.50
 \$92,187.50 ÷ 5,420 acres = \$17.01, average cost per acre.

Drainage Unit No. 23—Containing 1,595 acres, averages about 1½ miles wide on the east bank of the Kaskaskia river and extends from the proposed channel of Linn creek, a distance of 1½ miles to Suck creek cut-off.

The average height of the proposed river levee is 11.7'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	117,800 Cu. Yds.
Levee for Suck Creek.....	41,600 " "
Levee for Linn Creek.....	43,300 " "

Total 202,700 " " @ 12½c \$25,337.50
 $\$25,337.50 \div 1,595 \text{ acres} = \$15.88$, average cost per acre.

Drainage Unit No. 24—Containing 1,875 acres, averages about 1 mile wide on the west bank of the Kaskaskia river and extends from the city of Vandalia northerly about 3 miles to a point where the Kaskaskia river leaves the bluffs on the west side of the bottom lands.

In addition to the Kaskaskia river levee, it is proposed to protect this drainage unit from the waters of Bear creek by a diversion channel and levee beginning in the northwest corner and extending southerly along the Illinois Central Railroad; thence along the foot of the bluffs to an outlet into the Kaskaskia river at the south end of this drainage unit, near Vandalia.

The average height of the proposed river levee is 11.9'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	212,600 Cu. Yds.
Bear Creek Levee.....	18,100 " "

Total 230,700 " " @ 12½c \$28,837.50
 $\$28,837.50 \div 1,875 \text{ acres} = \$15.38$, average cost per acre.

Drainage Unit No. 25—Containing 1,275 acres, averages about three-quarter mile wide on the east bank of the Kaskaskia river and extends from Suck creek cut-off, a distance of about 3 miles northerly to where the Kaskaskia river leaves the bluffs on the east side of the bottom lands.

The average height of the proposed river levee is 12.4'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	245,200 Cu. Yds.
Suck Creek Levee.....	41,600 " "

Total 286,800 " " @ 12½c \$35,850.00
 $\$35,850.00 \div 1,275 \text{ acres} = \$28.12$, average cost per acre.

Drainage Unit No. 26—Containing 2,880 acres, averages 1½ miles wide on the west bank of the Kaskaskia river and extends from a point about 1 mile southerly from Vera bridge where the Kaskaskia river strikes the bluffs on the west side of the bottom lands, a distance of 4 miles northerly to the proposed channel for Ramsey creek.

Aside from the protection for this drainage unit by the proposed Kaskaskia river levee and the proposed levee along Ramsey creek channel, there is proposed a bluff ditch and levee beginning at the bluff about one-half mile southerly from the north end of this drainage unit, and extending southerly near the foot of the bluff, a distance of about 4 miles, to an outlet into the Kaskaskia river at the south end of this drainage unit.

The average height of the proposed river levee is 12.7'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	271,200	Cu. Yds.
Ramsey Creek Levee.....	41,800	" "
Bluff Ditch and Levee.....	104,600	" "
Total	417,600	" " @ 12½c \$52,200.00
\$52,200.00 ÷ 2,880 acres = \$18.13, average cost per acre.		

Drainage Unit No. 27—Containing 6,500 acres, averages 2 miles wide on the east bank of the Kaskaskia river and extends from the proposed Big creek channel northerly a distance of 6½ miles to the proposed channel for Hog creek. For this drainage unit there is planned a bluff ditch and levee beginning at the bluff near the north end of the drainage unit, extending southerly along the foot of the bluff to the proposed Big creek diversion channel, from which point the waters carried by this bluff ditch, together with the waters of Big creek, will be carried by diversion channel and levee along the foot of the bluff to an outlet into the Kaskaskia river at the lower end of this drainage unit.

The average height of the proposed river levee is 12.7'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	530,400	Cu. Yds.
Big Creek Levee.....	5,500	" "
Bluff Ditch and Levee.....	238,100	" "
Total	774,000	" " @ 12½c \$96,750.00
\$96,750.00 ÷ 6,500 acres = \$14.88, average cost per acre.		

Drainage Unit No. 28—Containing 3,475 acres, averages 1 mile wide on the west bank of the Kaskaskia river and extends from the proposed channel for Ramsey creek northerly a distance of 6 miles to a point about one-quarter mile south of Wren bridge.

For this drainage unit there is proposed a bluff ditch and levee extending from the upper end of this drainage unit southerly along the foot of the bluff about 5 miles to where Ash creek enters the Kaskaskia river bottoms from which point the waters from this bluff ditch, together with the waters from Ash creek, will be carried southerly along the foot of the bluffs by a channel and levee to an outlet into the proposed channel for Ramsey creek.

The average height of the proposed river levee is 13.9'.

The estimated cost of the local work for protection from overflow for this drainage unit is as follows:

Kaskaskia River Levee.....	626,500	Cu. Yds.
Ramsey Creek Levee.....	28,300	" "
Ash Creek Levee.....	47,400	" "
Bluff Ditch and Levee.....	170,600	" "
Total	872,800	" " @ 12½c \$109,100.00
\$109,100.00 ÷ 3,475 acres = \$31.40, average cost per acre.		

The numbers and areas of the drainage units and the area of the lands between the drainage units are shown in the following table:

AREA OF BOTTOM LAND.

Right Bank.			Left Bank.		Summary—Acres.
Drainage unit.	Acres.	Acres between units.	Drainage units.	Acres.	
2	4,390	590	1	1,765	In Drainage Unit—
4	10,945		2	7,635	On right bank.....
6	4,560		3	4,513	In Drainage Unit—
8	9,920		7	5,835	On left bank.....
10	8,870			450	
12	635	40	9	4,480	Not Leveed—
14	885			40	Right bank.....
16	2,800	840	11	1,990	Not Leveed.....
18	2,565		13	2,170	Left bank.....
20	4,620		15	9,745	
22	5,420	40	17	8,595	Shoal Creek Bottom—
24	1,875		19	6,085	Right bank.....
26	2,880				Left bank.....
28	3,475		21	14,720	
			23	1,595	Total above New Athens.....
		210	25	1,275	Below New Athens—
			27	6,500	Right bank.....
		2,500			Left bank.....
	63,830	4,220			Total.....
				76,950	180,700

INTERIOR DRAINAGE.

After the lands of any drainage unit are protected from overflow from the streams and hill waters, it is necessary to provide an adequate system of interior drainage. These river bottom lands are essentially flat and are not provided with natural channels necessary for outlet drainage. Open ditches and tile drains, therefore, are necessary for the reclamation of these lands. These drains must lead to a suitable outlet in the lower or down-stream portion of the drainage unit. No detailed studies have been made for the interior drainage of any of the drainage units. The cost will vary in these different drainage units, but the average cost will be about \$4.00 per acre for the interior drainage ditches, based upon experience with similar lands elsewhere.

THE OUTLET.

At low water in the Kaskaskia river there will be a sufficient outlet for the drainage of all the lands, and for this drainage a culvert, or sluiceway, built of concrete or iron pipe can be constructed through the levee with a suitable gate to prevent the water from backing up into the drainage ditches when the river is high. For removing the water from the drainage ditches when the river is high two methods are contemplated: (1) The construction of pumping plants or (2) the construction of "Gravity-Outlets." If, instead of opening a ditch through the levee into the river, the ditch were carried down-stream and along the levee such a distance that the fall in the stream would equal the height of the flow above the level in the river required to give good drainage to the land at the natural point for discharging the drainage ditch into the river channel, and then an outlet made through the levee for the ditch, the back water from the river could not then flood any of the lands drained by such ditch.

A secondary levee would be needed so as to prevent the back waters from flooding adjacent lands in the drainage unit through which, or along which the gravity outlet ditch is constructed. This secondary levee would diminish in height until it reached the natural point of discharge for the ditch along which it is built, at which point the levee would practically run out. The gravity outlet would be designed to carry the drainage of the district with a very small surface slope and, therefore, must be proportionately larger in cross-section. In this way the necessity of the construction and maintenance of pumping plants can be obviated and thorough drainage provided for. The practicability of the construction of gravity outlet depends upon the rate of fall of the main stream. The less the fall of the main stream the longer and, consequently, more expensive the gravity outlet. There are frequently natural barriers to the construction of sufficiently long gravity outlets to overcome the back water effect.

Gravity outlets have been designed and estimated for five of the drainage units in this territory. For all of the other drainage units it will be necessary to provide pumping plants, or permit the natural

drainage of the drainage unit to accumulate upon the lower lands within the drainage unit during high water in the Kaskaskia river. When the river recedes the sluiceways will open and permit of the discharge of the accumulated waters and drainage of the lands until the recurrence of another flood.

No detailed studies or estimates have been made for the cost of pumping stations and sluiceways, but the average cost for pumping stations and sluiceways will be about \$4.00 per acre for each drainage unit, based upon experience in similar lands elsewhere. The cost of pumping plants will vary according to the size of the unit, and the character and extent of the adjacent drainage area tributary thereto, if any.

The location of the bluff diversion ditches and gravity outlets is shown upon the plans. The approximate lengths by stationing, the elevations of the grade and the width of the bottom, and other details regarding the design of the bluff diversion ditches and gravity outlets are shown in the following table:

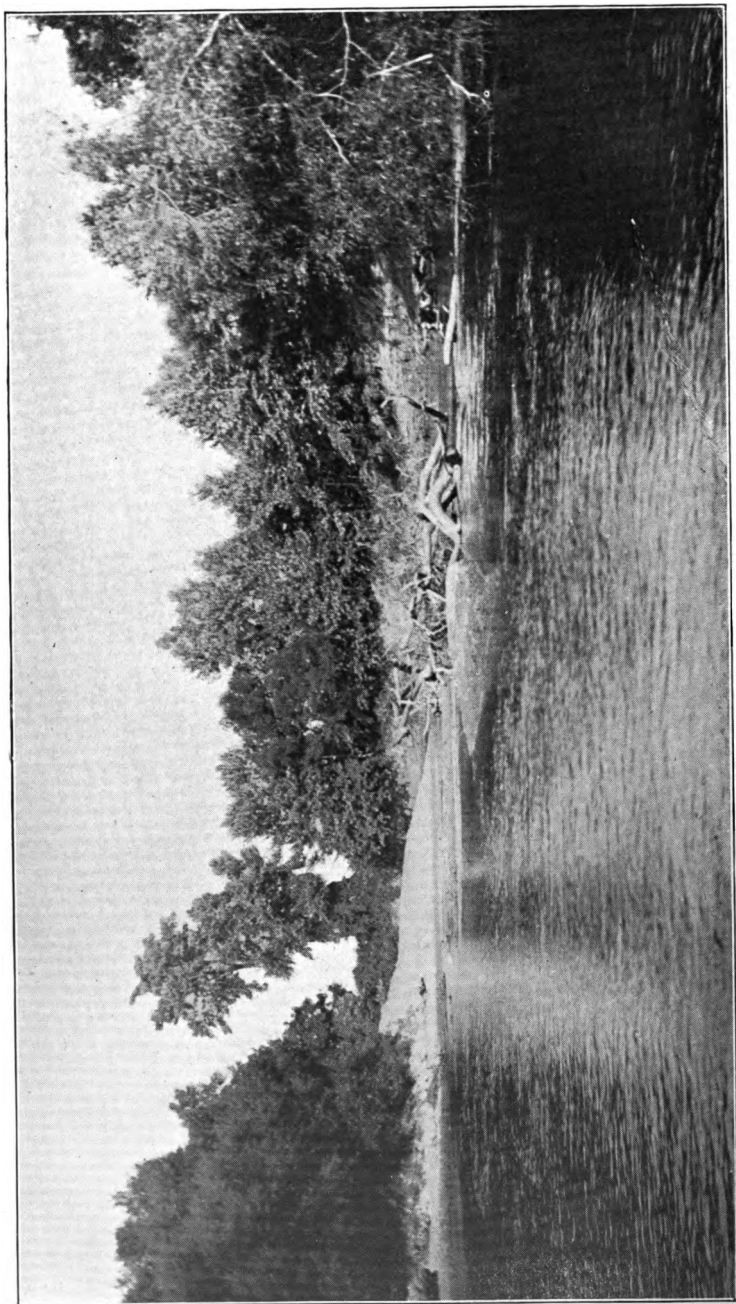
BLUFF DIVERSION DITCHES AND GRAVITY OUTLET DITCHES.

Bluff Ditch— for unit.	Bluff Ditch outlet— between units.	Gravity outlet— for unit.	Station.	Grade elevation.	Bottom width.	Bottom grade slope.	Location of station "O"	Levee.	
								Grade elevation.	Grade slope.
No. 2			0.000	378.0	8.	.00025	Sta. 6.0 Silver-Cr.	397.2	.00015
			4.000	379.0	8.	.00075			
			8.000	382.0	8.	.00025		400.2	
			20.000	385.0					
No. 3			0.000	363.0	8.	.00034	Sta. 13.0 Big Mud Creek	402.6	.0001
			32.000	393.9				405.8	
			0.000	385.0	8.	.00062	Sta. 250.7 Kaskaskia	406.1	.0003
			14.500	394.0	8.	.0028			
No. 5			17.000	401.0	8.	.00013		412.0	.0001
			20.000		8.			415.0	
			50.000	404.9					
			0.000	387.0	8.	.003	Sta. 15.0 Elkhorn Creek	410.5	.0001
			4.000	399.0	8.	.0001		411.0	
			16.000 18.000	400.2				412.4	
No. 6			0.000	394.0	8.	.00048	Sta. 7.0 Sugar Creek	418.9	.00005
			29.000	407.9				420.3	
No. 7			0.000	407.0	8.	.00015	Sta. 19.5 Plum Creek	419.0	.00015
			23.000	410.5				422.5	

KASKASKIA RIVER IMPROVEMENT.

Bluff Diversion Ditches and Gravity Outlet Ditches—Concluded.

Bluff Ditch— for unit.	Bluff Ditch outlet— between units.	Gravity outlet— for unit.	Station.	Grade elevation.	Bottom width.	Bottom grade slope.	Location of station "O"	Levee.	
								Grade elevation.	Grade slope.
No. 8	Nos. 8 and 10		0.000	408.9			Sta. 17.0 Bluff Ditch Outlet bet. 8 and 10	423.6	.00007
			19.500	411.8	8.	.00015		425.0	
			0.000	405.0			Sta. 33.0 Gravity out- let for Unit No. 10	421.0	.00007
No. 10			17.000	408.9	10.	.00023		423.6	.00015
			0.000	408.9	8.	.0003	Sta. 17.0 Bluff Ditch Outlet bet. units 8 and 10	423.6	
			27.000	417.0			Sta. 32.0 Kaskaskia	425.0	.00005
No. 15		No. 10	0.000	400.0	15.	.00012		418.7	.00007
			33.000	404.0	8.	.00012		421.0	
			39.000	404.7					
No. 16			0.000	410.0	8.	.002	Sta. 348.5 Kaskaskia	438.0	.00014
			5.000	420.0	8.	.00022		445.0	
			50.000	430.0			Sta. 480.0 Kaskaskia	444.9	.0001
No. 17		No. 17	0.000	425.0	8.	.0002		447.3	
			24.000	429.8			Sta. 419.0 Kaskaskia	438.0	.00005
			0.000	415.0	8.	.0002		440.4	
			48.700	428.0					
			65.500						



Sand bars and driftwood in bend.

KASKASKIA RIVER IMPROVEMENT.

[illegible]

ESTIMATES OF COST.

The work to be done in the reclamation of the Kaskaskia valley is divided under several headings: (1) The main channel of the Kaskaskia river; (2) tributary stream channels; (3) the Kaskaskia river levee; (4) the tributary stream levees; (5) the bluff ditches and levees; (6) the gravity outlet ditches and levees. This work should naturally be divided into two general classifications for purposes of management and distribution of the expense of the work, as follows:

First—As a general improvement, the correction and straightening of the channel of the main stream and the channels of the tributary streams within the overflowed area of the main stream; the cost to be charged against all of the overflowed lands within the valley which would be benefited.

Second—As local improvements, the levees protecting each drainage unit from overflow and all of the ditches and pumping plants required for such units; the cost to be charged against all of the lands to be benefited in such drainage unit.

A detailed description of each drainage unit, together with the estimated cost of the work on such unit for protection from overflow, has been heretofore given in this report.

A resumé of the quantities required for the improvements, under the headings hereinbefore mentioned, for the correction of the main stream and tributary stream channels, levees and ditches, is given in the following table:

YARDAGE TABULATION.

Name.	Kaskaskia channel.	Tributary stream channel.	Kaskaskia river levee.	Tributary stream levee.	Bluff Ditch and levee.	Gravity Ditch and levee.	Total.
Above New Athens....	6,246,700	-----	-----	-----	-----	-----	6,246,700
Below New Athens....	618,300	-----	-----	-----	-----	-----	618,300
Big Mud Creek.....	-----	87,400	-----	-----	-----	-----	87,400
Silver Creek.....	-----	82,200	-----	-----	-----	-----	82,200
Sugar Creek.....	-----	112,600	-----	-----	-----	-----	112,600
Elkhorn Creek.....	-----	136,200	-----	-----	-----	-----	136,200
Shoal Creek.....	-----	1,358,400	-----	-----	-----	-----	1,358,400
Plum Creek.....	-----	247,700	-----	-----	-----	-----	247,700
Crooked Creek.....	-----	907,600	-----	-----	-----	-----	907,600
East Fork Creek.....	-----	297,200	-----	-----	-----	-----	297,200
Louse Creek.....	-----	114,600	-----	-----	-----	-----	114,600
Hurricane Creek.....	-----	276,800	-----	-----	-----	-----	276,800
Buck Creek.....	-----	6,600	-----	-----	-----	-----	6,600
Bear Creek.....	-----	103,100	-----	-----	-----	-----	103,100
Linn Creek.....	-----	25,200	-----	-----	-----	-----	25,200
Ash Creek.....	-----	37,900	-----	-----	-----	-----	37,900
Ramsey Creek.....	-----	74,800	-----	-----	-----	-----	74,800
Hog Creek.....	-----	25,800	-----	-----	-----	-----	25,800
Suck Creek.....	-----	-----	-----	-----	-----	-----	-----
Big Creek.....	-----	241,200	-----	-----	-----	-----	241,200
Total.....	6,865,000	4,135,300	-----	-----	-----	-----	11,000,300

Yardage Tabulation—Concluded.

Name.	Kaskaskia channel.	Tributary stream channel.	Kaskaskia River levee.	Tributary stream levee.	Bluff Ditch and levee.	Gravity Ditch and levee.	Total.
Drainage. Unit.....	Carr'd fr'd 6,865,000	Carr'd fr'd 4,135,300					Carr'd fr'd 11,000,300
1.....			639,900	70,100			710,000
2.....			917,000	92,800	190,100		1,199,900
3.....			1,406,000	96,200	384,200		1,886,400
4.....			1,437,800	208,200	325,400		1,971,400
5.....			741,800	181,000	105,400		1,028,200
6.....			275,000	309,800	311,800		896,600
7.....			1,056,000	59,800	100,700		1,216,500
8.....			714,800	265,000	291,900		1,271,700
9.....			254,200	93,400			347,600
10.....			900,300		249,900	366,900	1,517,100
11.....			416,600				416,600
12.....			251,000				251,000
13.....			243,700				243,700
14.....			183,100				183,100
15.....			915,900	1,300	438,500		1,355,700
16.....			462,900		157,300		620,200
17.....			852,200	30,800		576,500	1,459,500
18.....			396,800	13,200	131,100		541,100
19.....			916,900			315,200	1,232,100
20.....			563,800	16,100			579,900
21.....			344,500	37,100		502,900	884,500
22.....			572,400			165,100	737,500
23.....			117,800	84,900			202,700
24.....			212,600	18,100			230,700
25.....			245,200	41,600			286,800
26.....			271,200	41,800	104,600		417,600
27.....			530,400	5,500	238,100		774,000
28.....			626,500	75,700	170,600		872,800
Total.....	6,865,000	4,135,300	16,466,300	1,742,400	3,199,600	1,926,600	34,335,200

The foregoing table shows that the total amount of excavation for the correction of the main stream and tributary channels is approximately 11,000,000 cubic yards; the total river levee approximately 16,500,000 cubic yards; the other levees and ditches approximately 7,000,000 cubic yards, or a total of a little over 34,000,000 cubic yards of fill and excavation for levees and ditches. In preparing the plans and estimates it has been considered that the excavation from main channel of the Kaskaskia river will not be available for levee construction, but that the levees must be built entirely independent of and, in most cases, remote from the location of the channel cut-offs. For the tributary stream channels and levees it has been considered that to a considerable extent the material excavated from the channels may be used for partial construction of levees, and the estimates have been based upon such use of the excavated material wherever considered practicable.

Gravity outlet ditches have been estimated for five of the drainage units, viz, Units Nos. 10, 17, 19, 21 and 22. The gravity outlets are designed and offered as a substitute for pumping plants, and are intended to furnish a free gravity outlet for the drainage of the lands at all stages of the Kaskaskia river. In considering the cost of these gravity outlets they are chargeable only to the drainage unit which they serve, and not to the general improvement, although they are included in the grand total. A detailed study of the location surveys may develop the desirability of furnishing gravity outlets to a few more of the drain-

age units, or of substituting pumping plants for some of these which have been estimated. It would be good economy to pay considerably more in first cost for a gravity outlet than for a pumping plant, owing to the saving in future maintenance, repairs and operation charges, and to the greater certainty of action under all flood conditions.

A general estimate of the cost is as follows:

Kaskaskia River Channel—	
6,855,000 Cu. Yds. @ 8c.....	\$548,400 00
Tributary Stream Channels—	
4,135,300 Cu. Yds. @ 12½c.....	516,912 50
	\$1,065,312 50
Kaskaskia River Levee—	
16,466,300 Cu. Yds. @ 12½c.....	\$2,058,287 50
Tributary Stream Levees—	
1,742,400 Cu. Yds. @ 12½c.....	217,800 00
Bluff Ditches and Levees—	
3,199,600 Cu. Yds. @ 12½c.....	399,950 00
	2,676,037 50
	\$3,741,350 00
Gravity Outlets—	
5 Drainage Units = 43,690 acres—1,926,600 Cu. Yds. @ 12½c	240,825 00
	\$3,982,175 00
Add 20% for Right of Way, Contingencies, Engineering, Administration, etc.....	
	796,435 00
Total	\$4,778,610 00

In the foregoing estimates the cost of the correction of the main channel of the Kaskaskia and tributary streams is grouped in one item and amounts to \$1,065,312.50. 160,000 acres above New Athens in the Kaskaskia and Shoal bottoms will be benefited by the correction of these stream channels. This portion of the work should be handled as a unit improvement and the cost charged against the land in accordance with the benefits to each tract. The average cost, based upon 160,000 acres, would be \$6.70 per acre.

The cost of the main river levee, the tributary streams, levees and bluff ditches and levees, is placed in a second group, the aggregate cost of which is \$2,676,037.50. About 140,000 acres of land will be benefited by these improvements, as no improvement for Shoal creek bottom is included in this item. The average cost on 140,000 acres is \$19.10 per acre.

The estimated cost for protection from overflow of the drainage units, exclusive of the general stream straightening, and interior drainage with proper outlets, is shown in the following table:

COST OF OVERFLOW PROTECTION FOR DRAINAGE UNITS.

Unit.	Acres.	Cost.	Cost per acre.	Unit.	Acres.	Cost.	Cost per acre.
1	1,765	\$ 88,750 00	\$50 28	2	4,390	\$149,987 50	\$34 16
3	7,453	235,990 00	30 81	4	10,945	246,825 00	22 55
5	4,515	123,525 00	28 47	6	4,550	112,075 00	24 63
7	5,335	152,062 50	26 06	8	9,920	158,962 50	16 02
9	4,480	45,450 00	9 70	10	8,870	189,637 50	21 35
11	1,990	52,075 00	26 17	12	635	31,375 00	49 41
13	2,170	30,462 50	14 04	14	855	22,987 50	25 86
15	9,745	169,472 50	17 39	16	2,800	77,525 00	27 69
17	8,595	182,437 50	21 23	18	2,565	67,637 50	26 37
19	6,985	154,012 50	25 31	20	4,620	72,587 50	15 71
21	14,720	110,562 50	7 51	22	5,429	92,187 50	17 01
23	1,595	25,337 50	15 88	24	1,875	26,937 50	15 38
25	1,275	35,850 00	28 12	26	2,880	52,200 00	18 13
27	6,500	96,750 00	14 88	28	3,475	109,100 00	31 40

Gravity outlets for the five drainage units for which they are proposed will serve an aggregate of 43,690 acres, and the average cost will be \$5.55 per acre.

If pumping plants should be used instead of gravity outlets, the average cost will probably be about \$4.00 per acre for the installation of pumping plants. This cost for pumping plants will also be necessary for the drainage units where no gravity outlets are provided. The necessary interior drainage ditches to carry the surface and sub-soil drainage to the proposed gravity or pumping plant outlets at the lower ends of drainage units have not been detailed, but will cost an average of \$4.00 per acre.

Taken as a whole, the estimated average cost of the entire improvement, based upon 160,000 acres of land to be benefited, is practically \$30.00 per acre, for the correction of the streams and for protection from overflow. The interior drainage, either by pumping or gravity outlets, will cost approximately \$8.00 per acre more, so that the reclamation of these lands will cost on an average of from \$35.00 to \$40.00 per acre. Some of the drainage units will cost much less, and some will cost considerably more.

CONCLUSIONS AND RECOMMENDATIONS.

From these investigations we would make the following conclusions and recommendations:

First—That the Kaskaskia valley contains a very large and fertile tract of land, which is now subject to overflow and in many respects worse than useless, but which may be reclaimed and made available for profitable farming.

Second—That the total benefits to be derived from the reclamation of this land will be from 50 to 100 per cent more than the cost of such improvements.

Third—That in order to carry out such an improvement effectively and efficiently it will be necessary to provide an organization to administer and control the entire improvement as a unit, and to maintain the improvement in a high state of efficiency after construction.

Fourth—As there is no law in the Illinois statutes under which such an organization can be readily effected, we recommend that a new drainage law be enacted which would be effective for the organization and management of large areas of overflowed and swamp lands.

Fifth—That the provisions of such a law should make it possible to carry out the general improvements at the cost of all the lands within the drainage district, and subsequently to develop each drainage unit at the cost of the land in such unit when the owners of the lands shall desire the same to be done.

Sixth—That the development of such an area of land should be progressive: (1) The correction of the main stream channels; (2) the development of the drainage units.

In the drainage units where there is much timber the construction of pumping plants or gravity outlets might be deferred until the owners of land can clear and put into cultivation the higher portions of the land, using the lower lands for reservoirs or storage for the drainage of the higher lands while the river is in flood; *provided*, that there shall be arrangements made for an equitable distribution of the cost of such deferred work as a part of the original work necessary for such drainage unit.

Respectfully submitted,
JACOB A. HARMAN, C. E.,
Engineer.

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